MINNEAPOLIS
Honeywell

Control manual

FOR

HEATING · VENTILATING
AIR CONDITIONING

AUTOMATIC CONTROLS MH

MINNEAPOLIS HONEYWELL REGULATOR COMPANY · MINNEAPOLIS

HONEYWELL

MINNEAPOLIS

MH

CONTROL MANUAL

for

HEATING, VENTILATING

and

AIR CONDITIONING

AUTOMATIC CONTROLS MH

MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
Minneapolis, Minnesota

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SECTION I

Printed in U. S. A.

What Makes Automatic Air Conditioning . . .

COMPLETE COORDINATION

AIR-CONDITIONING systems consist of many individual units of equipment, each designed to provide a specific function. The degree to which these functions are interlocked and coordinated determines the standards of operating economy and efficiency which will be maintained.

As the tendency today is toward including equipment for the purpose of accomplishing functions which previously have been ignored or left entirely to chance, the need for more careful consideration of this all-important "coordination" becomes increasingly imperative.

The proper application of adequate control has proved the most satisfactory and in the long run least expensive means of accomplishing coordination.

Minneapolis-Honeywell has recognized that no one type of control equipment may be considered uniformly desirable for all types of heating, ventilating, and air-conditioning systems and has therefore enlarged its design and manufacturing facilities to provide for the air-conditioning industry the only complete line of such equipment available.

Minneapolis-Honeywell offers electric, pneumatic, and self-contained type controllers, as well as Brown Instrument recorders, controllers, indicating thermometers, flow meters, and other instruments designed to provide operating records and data.

In addition to manufacturing equipment applicable to all types of installations, large or small, Minneapolis-Honeywell has also established a field installation and maintenance organization which is thoroughly qualified to render additional services to the entire industry. Branch offices in 38 cities are manned by factory-trained engineers who are in a position to undertake the supervision or installation of control systems on any one of the following bases:

• PARTIAL SUPERVISION

Where equipment has been purchased on a strictly delivered basis and only partial supervision is required, Minneapolis-Honeywell control experts are available on a flat daily rate to provide any or all of the following:

1. Engineering Service and preparation of installation diagrams.
2. Supervision of control installation.
3. Adjustments and testing of controls.
4. Final inspection and instruction for operators.
5. Subsequent service if required.

• CONTRACT INSTALLATION

When desired, Minneapolis-Honeywell will accept entire control responsibility and provide a quotation covering complete installation, as follows:

1. Provision of all necessary control units.
2. Complete design service and preparation of all control installation diagrams.
3. Installation of all controls, including wiring or piping (setting of valves and dampers is usually handled by the respective contractors).
4. Performance of all control tests, final inspection, and provision of operating instructions.
5. Service for a period of one year from date of completion of the installation unless otherwise contracted for.

• CONTRACT SUPERVISION

On those installations where it will prove advantageous for the purchaser to have the actual labor of installation, wiring or piping provided by others, a quotation covering equipment and supervision may be obtained. Under this type of contract Minneapolis-Honeywell assumes responsibility for the instruction and direction of installers and for inspection of work in progress.

The advantages to be gained in handling control jobs on either the Installation Contract basis or the Supervised Job Contract basis rather than on a straight purchase of material are as follows:

1. Control responsibility is centralized.
2. The contractor is relieved of all details attendant to the control problem.
3. Complete control cost is definitely fixed.
4. Assurance of proper operation of all controls.
5. A definite service responsibility is established for the specified period after installation.

• PERIODIC SERVICE

Minneapolis-Honeywell through its branch offices offers periodic service contracts for all jobs equipped with M-H controls. These contracts may be obtained to supplement installation or supervision contracts and are also available where equipment has been purchased on a delivered basis. The services included in this type of contract are:

1. Complete inspection of the control system at periodic intervals.
2. Adjustment, calibration, and cleaning of all M-H equipment.
3. Replacement of parts at a nominal charge.
4. Complete report to be rendered to contractor or user as directed.

Through the use of Minneapolis-Honeywell periodic service contracts, it is possible to obtain continued customer satisfaction, maximum efficiency of operation, and minimum maintenance cost.

. . . Installations Completely Successful?

THE RIGHT CONTROL FOR EVERY APPLICATION

FOR EVERY Air-Conditioning installation there is one combination of Automatic Control Units which will insure the desired program of operation at a minimum expense.

Obviously, no single control system can be considered as universally satisfactory because of the wide divergence between operating schedules which may be selected.

In designing a control system it therefore becomes necessary to carefully analyze all types of controls available and select that particular combination of units the characteristics of which will insure the exact functions for which the controls are to be installed.

PRINCIPLES OF CONTROL SYSTEMS

Controls may be broadly classified by considering them in relation to the primary operating media which they employ. Such classification indicates that there are five major groups into which they may fall:

1. Electric Control Systems.
2. Pneumatic Control Systems.
3. Combination Systems.
4. Self-Contained Systems.
5. Hydraulic Control Systems.

A brief description of each of these systems is listed below.

• ELECTRIC CONTROL SYSTEMS

In such control systems the primary medium utilized to provide operation is electricity. The basic function of these controls consists of switching or otherwise adjusting electric circuits to govern electric motors, relays or solenoids. The individual units of this type of system are inter-connected by line voltage or low voltage wiring.

• PNEUMATIC CONTROL SYSTEMS

In the pneumatic control systems, compressed air is used as the primary source of operation. The air pressure is varied by the controlling devices. In these systems one or more centrally located air compressors furnish a supply of compressed air which is distributed in special piping to the various controlling and controlled devices. By means of leak ports or orifices, the pressure of the air is varied in the branch lines and the changing pressures are utilized to provide the movement necessary to the operation of valves and dampers.

• COMBINED SYSTEMS

Experience has indicated that both electric and pneumatic control systems have inherent advantages which indicate their respective use for specific types of applications. It is only natural, therefore, that the two media should be combined to provide a system of control sharing the advantages of each. Combined systems are usually best adapted to large Air-Conditioning and Public Building installations.

• SELF-CONTAINED SYSTEMS

Self-Contained control systems have, in general, been restricted to such operations as could be effectively handled by a power unit with integrally mounted or direct connected controller. Such applications consist of valves utilized to admit steam or other media into coils to regulate the temperature of tanks or to regulate the admission of steam into heating coils as determined by the controller element. Such systems do not ordinarily contemplate wide separation of the controlling mechanism and the power unit.

• HYDRAULIC SYSTEMS

Liquid under pressure provides another easily controllable source of power and is occasionally used as a control medium.

CONTROL OPERATION

Control systems may be further classified into three general types as regards the characteristics of the motion imparted by the controls to the controlled equipment. These three classifications will be described in the following paragraphs. It must be remembered that very often heating, ventilating or air-conditioning systems under Automatic Control may make use of more than one and sometimes all of the three types of control in various phases or functions of the system. Following this broad discussion will be found pages outlining the actual basic circuits used in obtaining these actions.

• TWO-POSITION CONTROL

Two-position control is also referred to as "on and off" control or as "positive-acting" control. As an example, a simple thermostat which starts and stops an oil burner or a ventilating fan, or which opens and closes a solenoid valve, can merely select between starting and stopping of the fan or between opening and closing of the valve. There are no intermediate positions nor degrees of motion between the two

extremes of operation. Similarly, a two-position motorized damper would move between two fixed limits such as full closed and full open.

Two-position control is, in general, the simplest method of providing regulation. However, it has definite shortcomings in certain circumstances. These limitations will be discussed in detail under the chapters covering "Central Fan Heating and Cooling Systems".

Two-position systems are most generally used where the controlled device is one of the following:

1. Relay.
2. Solenoid Valve
3. Exhaust Damper.
4. Small Volume Damper.

• FLOATING CONTROL

Floating control is a designation applied to a control system in which a control valve or damper motor will operate when the controller makes contact at either extreme of its differential, coming to rest only when the controlled medium has stabilized between these limits. Floating Control may be used to advantage on applications where the movement of a motor valve or damper will produce a change in the controlled medium which will be reflected immediately at the controller unit.

Applications of this type are:

1. Static Pressure Regulation.
2. Tank Level Control.

• MODULATING CONTROL

The modulating control system is also designated as "gradual or graduated acting control" or "proportioning control". These names are synonymous as applied to Automatic Control and are used to designate the type of system in which a control valve or damper motor modulates or proportions the flow of air, steam or water in response to a change of conditions at the controller. Modulating control causes motion in the controlled device in proportion to motion produced in the controller by fractional degree variations in the medium to which the controller is responsive. After such fractional change has been measured at the controller and translated to terms of a new position of the valve or damper, the modulating system stands by awaiting further change at the controller. The extent of the motion is limited only by the limits of the controller and by the intensity of the change of conditions as measured, hence the valve or damper is repositioned as frequently as changes at the controller occur, but always in direct proportion to the amount of change.

Modulating control systems may be used on all applications where it is desirable to establish and maintain a large number of intermediate positions or stages between the two extremes of operation.

Automatic Control Equipment for Air Conditioning

IN order to simplify the selection of automatic control equipment for air-conditioning applications as much as possible, the following list of controls and supplementary equipment has been selected to illustrate and describe those units which are in most common use. This group of control equipment includes less than one-fourth of the Minneapolis-Honeywell line of automatic controls and it may be necessary, therefore, to refer to more complete catalogs describing other control equipment manufactured by the Minneapolis-Honeywell Regulator Company when special equipment is necessary.

The following are definitions of certain terms used in conjunction with the controls.

• LOW VOLTAGE

The term "low voltage" is used to indicate the use of 20 to 24-volt alternating current or of approximately 6-volt direct current as the actuating power for the control circuit. Low voltage alternating current is provided by the use of a transformer which reduces the main power supply from 115 or 230 volts to 20 to 24 volts. Low voltage direct current is seldom used, but when required is usually supplied by dry cells.

• LINE VOLTAGE

The term "line voltage" is used to indicate the use of 115 or 230-volt alternating or direct current as the actuating power for the control circuit. If the voltage of the supply line is higher than this, it is usually necessary to use two transformers, using one to reduce the voltage to 115 and the second to reduce to 20 to 24 volts.

• CONTROLLER DIFFERENTIAL

The operating differential of a controller is the change in a factor such as temperature or pressure which will produce a change in a controller contact from one position to another which will in turn operate a relay, motor, or motor valve from one extreme to another. The differential of a modulating controller, is frequently called throttling range.

ELECTRIC CONTROLS

THERMOSTATS

For Heating or Cooling Control

Most Minneapolis-Honeywell Thermostats are available for cooling control as well as heating control. Series 10 thermostats for cooling service must be specially manufactured with reverse acting temperature sensitive elements and cannot be used for both heating and cooling control unless used in conjunction with a special relay. Series 20, 60 and 90 thermostats are built and color coded as heating controls but can be used as cooling thermostats by merely interchanging the blue and white wires attached to the terminals. These groups of thermostats can be used for both heating and cooling by installing a manual double pole double throw switch which when changed from one position to the other will reverse the wiring. This change-over may also be made automatically by use of suitable relays and controllers. Series 40 thermostats for cooling must be ordered reverse acting.

THE ACRATHERM*

A bimetal actuated low voltage open contact thermostat for controlling relays, Protectorelays, gas valves, motors, etc. (Series 10 or Series 20) for heating application. Temperature setting by external dial at top. Silver finish.

Type	Action	Range	Differential	Electric Rating
T11A	Series 10, Heat Accelerated Action	55-85° F.	Adjustable	Low voltage A.C. only
T21A	Series 20, S.P.D.T. switching action, heat leveling action			Not applicable to D.C.

DIMENSIONS—Height $4\frac{3}{8}$", width, $1\frac{3}{4}$", depth, $1\frac{7}{8}$".

SPECIAL FEATURES AVAILABLE:

Cover Locking Screw, at no extra cost.
Positive Night Shut-off, at no extra cost.
Wall Plate (#23591A) for adapting to a wall switch box, at extra cost.
Blank Cover (less thermometer) at no extra cost.
"Positive On" at high end of scale at extra cost.

WHEN ORDERING SPECIFY:

1. Type Number.
2. Type Number, voltage and frequency of device Acratherm is to control.
3. Special features required.

*Trade Mark

THE DA-NITE ACRATHERM*

A bimetal actuated low voltage open contact thermostat affording lowered night temperatures and automatic morning pick up (Series 10 or Series 20) for heating application. Temperature settings by external dial at top. Has knob for night shutdown. Silver finish.

Type	Action	Range	Differential	Electric Rating
T109A	Series 10, heat accelerated type	Day 55-85° F. Night 45-75° F.	Adjustable	Low voltage A.C. only
T209A	Series 20, S.P.D.T. switching action, heat leveling type			Not applicable to D.C.

DIMENSIONS—Height, $5\frac{3}{4}$", width, $2\frac{1}{4}$", depth, $2\frac{7}{8}$".

SPECIAL FEATURES AVAILABLE:

Locking Device for day and night cycles at extra cost.
Cover Locking Screw at no extra cost.

WHEN ORDERING SPECIFY:

1. Type number.
2. Type number, voltage and frequency of device Da-Nite Acratherm is to control.
3. Special features required.

*Trade Mark

ELECTRIC CONTROLS

THERMOSTATS

THE CHRONOTHERM*

An electric clock thermostat providing automatic switching to lower night temperature and automatic return to day setting in the morning. Clock is operated by a self-starting Telechron motor; thermostat is bimetal actuated. Morning and night time settings and temperature adjustments are concealed by cover. External temperature indicator can be used to set temperature up manually after night shut-down. Finished in silver.

Type	Action	Range	Differential	Elec. Rating	Voltage of Clock Transformer (Separate)	Week-end & Holiday Shutoff
T111A	Series 10, heat accelerated type	56-84° F.	Adjustable	(Thermostat) Low voltage A.C. only	115 volts, 60 cycle 115 volts, 25-50 cycles or 230 volts, 50-60 cycles at extra cost	Not available
T211A	Series 20, S.P.D.T. switching action, heat leveling type	(only)				

DIMENSIONS—Height, 3⅝", width, 5¼"; depth. 2½".

SPECIAL FEATURES AVAILABLE:

Positive Night Shut-off at no extra cost.
Locking Cover at no extra cost.

*Trade Mark

WHEN ORDERING SPECIFY:

1. Type number.
2. Voltage, frequency and type number of device Chronotherm is to control.
3. Voltage and frequency for Chronotherm.
4. Special features required.

HEAVY DUTY SNAP ACTING THERMOSTATS

These thermostats are available for heating and/or cooling applications. Designed for use where accurate and dependable control of line voltage, heavy duty devices are involved, they are capable of handling directly large motor driven units, coal blowers, cooling equipment, industrial and commercial stoker fired heating plants, etc. On larger or polyphase motors, they can be used with magnetic starters. Applicable to low voltage circuits if desired.

Horizontal design provides maximum air circulation. Models TA42A and TA42B are equipped with a non-magnetic Con-Tac-Tor Snap Switch, self-enclosed to protect it from dirt, dust, moisture or grime. Has temperature setting knob which can be removed to lock the thermostat to discourage tampering and unauthorized adjusting.

Models TA42C and TA42D, listed by Underwriters' Laboratory, Inc., are arranged with switch enclosed in heavy explosion proof case for safe mounting in hazardous atmospheres. Case tapped for ¾" conduit.

Type	Switch	Action on Temperature Drop	Range	Differential	Electric Rating A.C.	Electric Rating D.C.
TA42A TA42C	S.P.S.T.	Close	45-75° F.	(Both Types) Non-adjustable 2° F. approx.	10 amps. 115-230 V. 1 H.P., 115 V. 1½ H.P., 230 V.	(Both Types) 2 amps., 24 V. 1.5 amps., 32 V. .2 amps., 115 V. .1 amp., 230 V.
TA42B TA42D	S.P.S.T. or S.P.D.T.	Open (S.P.S.T.)	45-75° F. 65-95° F.		4 amps. 115-230V. ¼ H.P., 115 V. ⅓ H.P., 230 V.	

DIMENSIONS—(TA42A & B) Height, 2⅞"; width, 5"; (including knob), depth, 2 3/16"
(TA42C & D) Height, 5 3/16"; width 6¼"; depth 4 13/16".

SPECIAL FEATURES AVAILABLE:

Adapter plate for mounting TA42A and B on vertical switch box at extra cost. (#33410A).
Conduit adapter for hanging TA42A and B thermostats in space at extra cost.

Positive "on" switch at extra cost—all models.

WHEN ORDERING SPECIFY:

1. Type number.
2. Range.
3. Special features required.

ELECTRIC CONTROLS

THERMOSTATS

MERCURY SWITCH THERMOSTATS

Mercury Switch type, bellows actuated thermostat for use with either line or low voltage primary equipment. Mercury switch contacts are protected from dust and corrosion. Has temperature adjusting knob on side of case. Finished in silver.

Type	Switch	Action on Temperature Drop	Range	Differential	Electric Rating
T42H	2 S.P.S.T.	Close two circuits in sequence	40-80° F. and 60-100° F.	2° F. non-adjustable per stage. Adjustable 1 to 5° F. between stages.	1 amp.—115 volts ½ amp.—230 volts 1/20 H.P.A.C. 1/30 H.P.D.C.
T42J	2 S.P.S.T.	Open two circuits in sequence			
T42K	2 S.P.S.T.	Open one circuit, closes one circuit			

DIMENSIONS—Height, 5⅞"; width, 3¾"; depth, 2¼".

SPECIAL FEATURE AVAILABLE:

Locking Device (at no extra cost).

WHEN ORDERING SPECIFY:
1. Type number.
2. Electrical motor rating — including normal running current. If M-H device is to be controlled, include its type number, voltage and frequency.
3. Locking Device, if required.

LIGHT DUTY LINE VOLTAGE SNAP ACTING THERMOSTATS

Magnetic Snap Acting bimetal actuated room thermostat, suitable for either line or low voltage application. S.P.S.T. switching action. Temperature setting by external lever at bottom. Silver finish.

Type	Action on Temperature Drop	Range	Differential	Electric Rating
T44A	Close	54-86° F.	Adjustable 1½° to 6°	5 amps.—115 volts 2½ amps.—230 volts A.C. 15 volt amps.—250 volts D.C. max. ¼ H.P.A.C. low starting current

DIMENSIONS—Height, 5"; width, 2"; depth, 1⅞".

SPECIAL FEATURES AVAILABLE:

Locking Device—Cover lock screw (at no extra cost).

Night Shut-off at no extra cost.

WHEN ORDERING SPECIFY:
1. Type number.
2. Type number, voltage and frequency of device Thermostat is to control—Include normal running current of motor if used.
3. Special features required.

HEATING-COOLING THERMOSTAT ASSEMBLY

FOR USE WITH T44 THERMOSTAT

Heating-Cooling Thermostats are used for controlling the operation of equipment capable of both heating and cooling functions.

Standard Snap Action Thermostat (T44) can be combined with special Heating-Cooling switches, which include a manual switch. The switch affords a "heating", a "cooling" and an "off" position.

The combination of a T44 Thermostat with a Q18A Switch affords conventional heating control when the manual switch is in the "heating" position. When the switch is moved to "cooling" the circuit is continually energized, thereby providing continuous operation of a fan.

TYPE
Q18A (Does not include thermostat).
DIMENSIONS — (For thermostat including Switch.)
Height, 5¾"; width, 2½"; depth; 2¾".

WHEN ORDERING SPECIFY:
1. Thermostat completely as per ordering specifications under Snap Action Thermostat.
2. Type number of switch.

ELECTRIC CONTROLS
THERMOSTATS

PROPORTIONING (POTENTIOMETER) THERMOSTATS

Potentiometer Thermostats are available for use with Series 90 proportioning equipment only. They are bellows actuated, and are used in control circuits where modulation of the controlled device is required. Operating bellows, vapor filled.

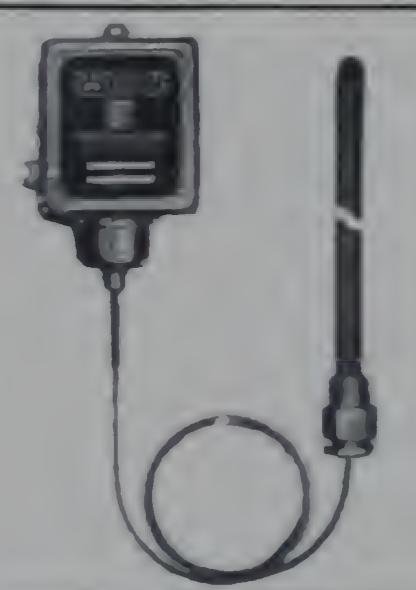
Screw driver adjustment is under locking cover. Silver finish.

Type	Switch	Potentiometer Size	Differential	Range	Electric Rating
T92A	Single potentiometer	1/16" or 1/4"	Non-adj. 3° F.	63-87° F. 48-72° F.	Low voltage A.C. only
T92B	Two potentiometers for controlling two circuits simultaneously or in sequence	1/64" or 1/4"	Non-adj. 3° F.	63-87° F.	
T92E	Two potentiometers for controlling two circuits simultaneously or in sequence	1/64"	Adjustable 2° to 6° per coil	63-87° F.	
T92G	Single potentiometer. Series 20 contact in sequence on low side	1/16"	Non-adj. 3° F.	63-87° F.	
T92H	Single potentiometer. Series 20 contact in sequence on high side	1/16"	Non-adj. 3° F.	63-87° F.	

DIMENSIONS—Height, 5 3/8"; width, 3 1/8"; depth, 2 7/8".

SPECIAL FEATURES AVAILABLE:
External thumb screw adjustment at top of case at no extra cost.

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.
3. External thumb screw adjustment, if required.



REMOTE BULB THERMOSTATS
Mercury Switch Type

For use where control element must be mounted in water lines, air streams and other inaccessible mediums. Operating element consists of a vapor filled tubing and bellows. Series 40 or 60 switching action for line or low voltage application. Mercury switch contacts. Five foot element standard; special lengths of 10 ft. available at extra cost. Capsule is copper. Temperature adjustment made by screws on top of case.

Type	Switch	Action on Temperature Drop	Range	Differential Low	Differential High	Bulb Size	Fittings
T415A T415B T615A	S.P.S.T. S.P.S.T. S.P.D.T.	Close Open Close, makes R-B circuit; Open, makes R-W circuit	0-70° F.✣ 15-90° F.*✣ 60-100° F.✣ 65-140° F. 80-210° F.† 105-220° F. 160-280° F.*	1° 4-27° 1° 4-27° 5-29° 5-29° 6-32°	1° 3-13° 1° 3-13° 3-14° 3-14° 4-15°	14 1/2"x11/16" 14 1/2"x11/16" 14 1/2"x11/16" 14 1/2"x11/16" 4"x 1/2" 4"x 1/2" 4"x 1/2"	3/4" 3/4" 3/4" 3/4" 1/2" 1/2" 1/2"
T415F	2 P.S.T.	Close two circuits in sequence	0-70° F. 15-90° F.* 60-100° F. 65-140° F. 105°-220° F.	1 3/4° per stage & 1 3/4° between stages for 0-70 only. Others: 1 1/2° per stage & 1 1/4° between stages		14 1/2"x11/16" 14 1/2"x11/16" 14 1/2"x11/16" 14 1/2"x11/16" 4"x 1/2"	3/4" 3/4" 3/4" 3/4" 1/2"
T415G	2 P.S.T.	Open two circuits in sequence	0-70° F.✣ 15-90° F.* 60-100° F.	1 1/2° per stage & 1 1/4° between stages		14 1/2"x11/16" 14 1/2"x11/16" 14 1/2"x11/16"	3/4" 3/4" 3/4"

* Special ranges available at extra cost.
†Special range available in T415A & T415B only (at extra cost).
✣Available in these ranges and types with limited fill element (1/2" x 4" bulb) at extra cost.
DIMENSIONS—Height from bottom of bellows housing 7 1/4" (except 65-140° range, 6 1/4"); width 4 1/4"; depth 2 3/4"

ELECTRICAL RATING—

Type	115 Volts (Amps.)	230 Volts (Amps.)	Horsepower R.I.	Horsepower S.P.	Horsepower D.C.
T415A, B	10	5	1*	1/2#	1/4
T415F, G	1	1/2	1/20	1/20	1/30
T615A	1	1/2	1/20	1/20	1/20▲

*3/4 H.P. for 15-90°, 65-140°, 80-210° and 105-220°. #1/4 H.P. for 15-90°, 65 to 140°, 80-210° and 105 to 220°.
▲For 15-90°, 65-140°, 80-210° and 105-220° only

SPECIAL FEATURES AVAILABLE (at extra cost):
Adjustment Means—Thumb screw. Order by Type No. W11A.
Separable Wells—Copper, mild steel, st. steel and monel.
Special mercury tube with 1/2° differential (except 1 1/2° for 80 to 210° and higher ranges). Electrical rating: 2 amps. 110 volts, 1 amp. 220 volts. 1/12 H.P.R.I., 1/20 H.P.S.P. and D.C.
Mild Steel Capsule.

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.
3. Element length.
4. Special features required.

ELECTRIC CONTROLS
THERMOSTATS

REMOTE BULB THERMOSTATS
Potentiometer Type

Potentiometer type Remote Bulb Temperature Controllers are used where modulating control is required. They are designed to operate with Series 90 motors and relays. Operating element consists of vapor filled tubing and bellows. Five foot element standard; special lengths of 10 ft. available at extra cost. Capsule is copper. Temperature adjustment made by screws on top of case.

Type	Switch	Range	Modulating Range†	Bulb Size	Fittings	Electric Rating
T915A	Single Potentiometer	0- 70° F.● 15- 90° F.*● 60-100° F.● 65-140° F. 80-210° F.* 105-220° F. 160-280° F.*	Non-adjustable 3° F.	14½"x11/16" 14½"x11/16" 14½"x11/16" 14½"x11/16" 4"x½" 4"x½" 4"x½"	¾" ¾" ¾" ¾" ½" ½" ½"	
T915B	Two potentiometers for controlling two circuits simultaneously or in sequence	0- 70° F.● 15- 90° F.*● 60-100° F.● 65-140° F. 105-220° F. 160-280° F.*	Non-adjustable 3° F.	14½"x11/16" 14½"x11/16" 14½"x11/16" 14½"x11/16" 4"x½" 4"x½"	¾" ¾" ¾" ¾" ½" ½"	
T915C	Single Potentiometer	—25- 0° F.* 0- 70° F.● 15- 90° F.*● 60-100° F.● 65-140° F. 80-210° F.* 105-220° F. 160-280° F.*	Adjustable 29-122° F. 8- 52° F. 7- 38° F. 6- 39° F. 6- 40° F. 6- 32° F. 6- 32° F. 6- 32° F.	14½"x11/16" 14½"x11/16" 14½"x11/16" 14½"x11/16" 14½"x11/16" 4"x½" 4"x½" 4"x½"	¾" ¾" ¾" ¾" ¾" ½" ½" ½"	Low voltage A. C. only
T915D	Two potentiometers for controlling two circuits simultaneously	0- 70° F.● 15- 90° F.*● 60-100° F.● 65-140° F. 75-105° F.* 80-210° F.* 105-220° F. 160-280° F.*	Adjustable 8- 52° F. 7- 38° F. 6- 39° F. 6- 40° F. 25-125° F. 6- 40° F. 6- 32° F. 6- 32° F.	14½"x11/16" 14½"x11/16" 14½"x11/16" 14½"x11/16" 4"x½" 4"x½" 4"x½" 4"x½"	¾" ¾" ¾" ¾" ½" ½" ½" ½"	
T915M	Single potentiometer and set of snap acting series 20 contacts	0- 70° F. 60-100° F. 65-140° F. 105-220° F.	Non-adjustable 3° F. (Series 20—½°)	14½"x11/16" 14½"x11/16" 14½"x11/16" 4"x½"	¾" ¾" ¾" ½"	

*Special ranges available at extra cost.
●Available in these ranges and types with limited fill element (½" x 4" bulb) at extra cost.
†Values shown correspond to mid-scale setting, slightly wider for low setting—slightly narrower for high setting.
DIMENSIONS—Height, 6⅞"; width, 5"; depth, 3".

SPECIAL FEATURES AVAILABLE (at extra cost):
Adjustment Means—Thumb screw. Order by Type No. W11A.
Separable Wells—Copper, mild steel, st. steel and monel. Mild Steel Capsule.

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.
3. Element length.
4. Special features required.

DIFFERENTIAL THERMOSTAT

The differential thermostat reacts to changes in the difference in temperature between two points. This device may be used as a controller for maintaining a certain difference in temperature or may operate as an alarm switch. Has grime proof cast case. Five foot element standard; 10 ft. elements available at extra cost.

Type	Action on Decrease in Temperature Difference	Electric Rating
L443A	Close	10 amps.—115 volts 5 amps.—230 volts 1 H.P.R.I.—½ H.P.S.P.— ¼ H.P.D.C.
L443B	Open	
L643A	S.P.D.T.	8 amps.—115 volts 4 amps.—230 volts ½ H.P.R.I.—1/6 H.P.S.P. or D.C.
L943A	Single potentiometer	Low voltage A.C. only

DIMENSIONS—Height, 8¾"; width, 9¼"; depth, 3".

ELEMENT LENGTHS—Five ft. element standard; 10 ft. elements available at extra cost.

RANGE AND DIFFERENTIAL—

Difference in Temperature to be Maintained		Contact Differential		Limits to Which Control May be Subjected		Capsule Size
Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
0°	50°	4°	20°	0°	120°	14½x11/16"
0°	40°	4°	20°	65°	170°	14½x11/16"
0°	40°	4°	23°	105°	225°	4x½"

WHEN ORDERING SPECIFY:
1. Type number.
2. Range (difference in temperature to be maintained).
3. Maximum and minimum temperatures to which system will be subjected.
4. Element lengths.
5. Complete details as to general application desired.

ELECTRIC CONTROLS
THERMOSTAT ACCESSORIES

THERMOSTAT GUARDS

Where thermostats require protection against tampering and theft, these devices are very useful. The Q51A is primarily designed for factory, gymnasium and similar usage where protection against damage is also required. It is equipped with locking device. The Q91A is a plain non-locking guard. Finished in black.

TYPES

Q51A Guard for all except Clock Type Thermostats.
Q91A Guard for T111, T211 and TA42 Thermostats.
Q92A Guard for T11, T19, T44, T801 Thermostats, etc.

DIMENSIONS—Height, 8"; width, 4½"; depth, 3⅝".

FINISH—Black Kristo-Krak.

WHEN ORDERING SPECIFY:

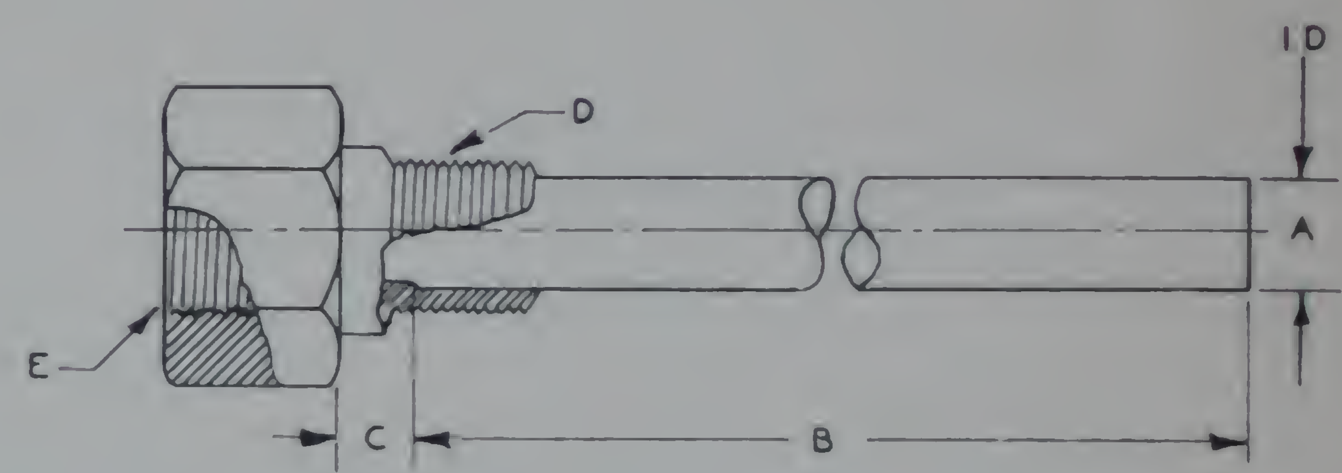
1. Type number.
2. Thermostat to be covered.

SEPARABLE WELLS FOR REMOTE BULB THERMOSTATS

In general, separable wells are required for protection of the capsule of a temperature controller from mechanical or chemical damage, or where it is necessary to provide for easy removal of the capsule from the medium it is controlling. Separable wells are also required to protect capsules where the capsule is to be immersed in a fluid in rapid or turbulent motion. In addition, a separable well provides a tighter seal for the medium controlled than a packing nut applied only to the capillary tubing.

When a separable well is required to protect the capsule from corrosion, the temperature, pressure and chemical analysis of the medium to be controlled should be specified for selection of proper well material.

Copper wells are soldered; the head of the well being brass; the tubing being copper. Mild steel wells are made up with welded joints at end of tubing and at connection of tubing to head of well.



FOR USE WITH ⅜" x 4" CAPSULES

INSIDE DIAMETER "A"		7/16"			
INSIDE TAPPING "E" (PIPE THREAD)		½"			
NECK LENGTH "C"		¼"		3¼"	
OUTSIDE TAPPING "D" (PIPE THREAD)		½"	¾"	½"	¾"
MATERIAL	LENGTH "B"				
COPPER	4¼"	23187A	23268A	60806A	23409A
MILD STEEL	4¼"	23269A	23332A	23778A	33107A

FOR USE WITH ½" CAPSULES

INSIDE DIAMETER "A"		.527"			
INSIDE TAPPING "E" (PIPE THREAD)		½"			
NECK LENGTH "C"		¼"		3¼"	
OUTSIDE TAPPING "D" (PIPE THREAD)		½"	¾"	½"	¾"
MATERIAL	LENGTH "B"				
COPPER	4¾" 8¾" 12"	23904A 23904C 23904B	23958A 23958C 23958B	33092A 33092C 33092B	23953A 23953C 23953B
MILD STEEL	4¾" 8¾" 12"	23507A 23507C 23507B	23959A 23959C 23959B	33159A 33159C 33159B	33158A 33158C 33158B

FOR USE WITH 11/16" CAPSULES

INSIDE DIAMETER "A"		¾"	
INSIDE TAPPING "E" (PIPE THREAD)		¾"	
OUTSIDE TAPPING "D" (PIPE THREAD)		¾"	
NECK LENGTH "C"		¼"	3¼"
MATERIAL	LENGTH "B"		
COPPER	15¼" 18¼"	23275A 23275B	23417A 23417B
MILD STEEL	15¼" 18¼"	23339A 23339B	23502A 23502B

ELECTRIC CONTROLS

AQUASTATS—AIRSTATS

AQUASTATS★

These devices are used as limit controls to prevent the operation of unit heater fans when there is no steam in the heater coil. They may also be used as limit controls on any hot water heating system.

Has marked scale and screwdriver slot through cover for adjusting.

Type	Action on Temperature Drop	Range*	Electrical Rating	Differential
LA209A	S. P. D. T. (Series 20)	100-200° F.	Low voltage	Non-adjustable, approximately 10° F.
LA409A	Close (Series 40)	100-200° F.	10 amps.—115 volts 5 amps.—230 volts 1 H.P.A.C. ¼ H.P.D.C.	
LA409B	Open (Series 40)			

* Standard ranges available in Centigrade scale at extra cost.
CASE DIMENSIONS—Height, 4⅜"; width, 3"; depth, 2⅛".

WHEN ORDERING SPECIFY:

1. Type number.
2. Range.

★Trade Mark

AIRSTAT★

(Fan Safety Cutoff)

The Fan Safety Cutoff is designed to stop fan operation whenever the temperature in the ducts rises to a point which indicates the presence of a fire. The device requires manual resetting following shut down in order to again start the fan.

Although a fan cutoff device is not required by all local codes, it is advisable to install one on any central fan installation.

Has swivel mounting bracket (see illustration) or surface mounting (without swivel bracket but with mounting holes in back of case). Screwdriver slot through cover provides adjustment.

Type	Action on Temperature Drop	Range	Electric Rating	Element Length
LA419D	Close	45-125° F. 75-165° F.	10 amps.—115 volts A.C. 5 amps.—230 volts A.C. 1 H.P.A.C.—¼ H.P.D.C.	10¼" maximum insertion

CASE DIMENSIONS—Height, 4⅜"; width, 3"; depth, 2⅛".

WHEN ORDERING SPECIFY:

1. Type number.
2. Range.

★Trade Mark

See Electronic Humidity Control – Bulletin SA 1804 – H58 Nov 1951

ELECTRIC CONTROLS

HUMIDITY AND PRESSURE CONTROLS

Mercury Switch Type

"Snap Action" Type

HUMIDITY CONTROLS

A sensitive human hair element is used to actuate switch in M-H Humidity Controls. Models are available with S.P.D.T. or S.P.S.T. switching action suitable for use in controlling 2-wire or 3-wire line or low voltage circuits. Used for either humidifying or dehumidifying control. Two general types are available — with "snap action" or mercury switch contacts.

H63A adjusted by indicator lever. Other models adjusted by external knob. Silver finish.

Type	Switch	Action on Humidity Rise	Differential	Electrical Rating	Range	Dimensions
H41A	Two-wire Mercury Switch	Open	3% R.H.	2 amps.—115 volts 1 amp. —230 volts	20 to 80% R.H.	Height—5 1/4" Width —2 3/4" Depth —2 11/16"
H41B	Two-wire Mercury Switch	Close				
H61A	Three-wire Mercury Switch	Close R to W	5% R.H.	1 amp. —115 volts 1/2 amp. —230 volts		
H63A	Three-wire Snap Action	Close R to W	2% R.H.	1 amp. —115 volts 1/2 amp. —230 volts	20 to 96% R.H.	Height—5" Width —2 1/2" Depth —2"

SPECIAL FEATURES AVAILABLE:
- Locking cover for H63A available at no extra cost.
- Locking cover, Key set for H41 and H61 at extra cost.

WHEN ORDERING SPECIFY:
1. Type number.
2. Special features required.

Type "P"

Type "L"

PRESSURETROLS*—MERCURY SWITCH TYPE

Mercury Switch Pressuretrols may be utilized as controlling or limiting devices in line or low voltage circuits. Mercury Switch contacts are operated by variations in pressure. Two general types are available—Type "P" with the actuating bellows located inside of the case, for 0 to 10 lbs. only, and Type "L" with external bellows for the higher ranges. Main scale and differential adjusting screws at top of case.

Type	Action on Pressure Drop	Electric Rating	Range*	Differential
P204A	Open R-W circuit (Series 20)	Low voltage A.C. only	"P" models 0 to 10 lbs.	Adjustable 1 to 5 lbs.
			L604A 0 to 15 lbs.	Adjustable 9 ozs. to 6 lbs.
L404A and P404A	Close (Series 40)	10 amps.—115 volts 5 amps.—230 volts 1 H.P.A.C.— 1/4 H.P.D.C.	All "L" models 2 to 50 lbs.	Adjustable 2 to 12 lbs.
L404B and P404B	Open (Series 40)		5 to 150 lbs.	Adjustable 5 to 16 lbs.
L604A	Open R-W circuit (Series 60)	1 amp. —115 volts 1/2 amp. —230 volts 1/20 H.P.A.C. and D.C.	10 to 300 lbs.	Adjustable 5 to 40 lbs.

* Kilogram equivalents of above shown on same scale on "P" models. Available at no extra cost on "L" models.
DIMENSIONS—Case: "P" models; Height 3 7/8"; width 3 1/2"; depth, 2 3/4". "L" models; Height, 4"; width, 3 1/2"; depth, 2 1/2".

SPECIAL FEATURE AVAILABLE (at extra cost):
Thumb screw adjustment means.

*Trade Mark

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.
3. Special feature required.

ELECTRIC CONTROLS
PRESSURE CONTROLS—VACUUMSTATS—VAPORSTATS

VAPORSTATS*—MERCURY SWITCH TYPE

The Mercury Switch type Vaporstat is used extensively as a limiting device in control systems regulating the operation of vapor steam boilers. These units are available for either low or line voltage applications. Main scale and differential adjusting screws at top of case.

Type	Action on Pressure Drop	Range	Electric Rating	Differential
L408A	Close (Series 40)	0-16 oz. or 0-4 lb.	10 amps.—115 volts 5 amps.—230 volts 1 H.P.A.C.—¼ H.P.D.C.	Adjustable 2-16 oz.
L408B	Open (Series 40)			
L608A	Makes W to R (Series 60)	0-16 oz.	1 amp. —115 volts ½ amp. —230 volts 1/20 H.P.A.C. and D.C.	

DIMENSIONS—Case: Height, 4"; width, 3½"; depth, 2½".

WHEN ORDERING SPECIFY:
1. Type number. 2. Range.

*Trade Mark

VACUUMSTATS*— MERCURY SWITCH TYPE

The Mercury Switch Vacuumstat is designed to operate as a limiting device when used in conjunction with a room Thermostat or to provide direct control of vacuum pressure heating systems. This control should be used only on installations employing a vacuum pump, since loss of vacuum may prevent proper control of the heating system. Mercury Switch contacts are satisfactory for line or low voltage applications. Main scale and differential adjusting screws at top of case.

Type	Action on Pressure Drop	Range	Differential	Electric Rating
L411A	Close	22" vacuum to 35 lbs.	Adjustable 4" vacuum to 30 lbs.	10 amps.—115 volts 5 amps.—230 volts 1 H.P.A.C.—¼ H.P.D.C.
L411B	Open			

DIMENSIONS—Case: Height, 4"; width, 3½"; depth, 2½".

WHEN ORDERING SPECIFY:
1. Type number.

*Trade Mark

PRESSURE CONTROLLERS—POTENTIOMETER TYPE

Potentiometer type pressure controllers are designed for use with Series 90 modulating control equipment. They may be applied wherever it is required to regulate the speed or capacity of heating or cooling equipment in a gradual manner. These controllers are available with an adjustable modulating range and are to be used only with other Series 90 equipment. Main scale and differential adjusting screws at top of case.

Type	Potentiometers	Available Adjustment & Modulating Range						Electric Rating
		0-15#	†22"-35#	†0-16 oz.	†2-50#	†5-150#	†10-300#	
L91A*	One	½ lb.	2 lbs.	1 oz.	2 lbs.	5 lbs.	10 lbs.	Low voltage A.C. only
L91B	One	1-12 lbs.	5-32 lbs.	2-38 ozs.	4-32 lbs.	11-52 lbs.	20-110 lbs.	
L91D	Two	1-12 lbs.		2-38 ozs.	4-32 lbs.	5-23 lbs.	Min. 20 lbs.	

*Non-adjustable modulating range. †Ranges available at extra cost. DIMENSIONS—Case: Height, 4"; width, 3½"; depth, 2½".

WHEN ORDERING SPECIFY:
1. Type number. 2. Range.

ELECTRIC CONTROLS
PRESSURE CONTROLS AND REGULATORS

DIFFERENTIAL PRESSURETROL*

The differential pressure controller reacts to changes in the difference in pressure between two points. This device may be used as a controller for maintaining a certain difference in pressure or may operate as an alarm switch. Has grime proof cast case.

Type	Switch	Action	Electric Rating
P406A	S.P.S.T.	Close on Decrease of pressure difference	10 amps.—115 volts 1 H.P.R.I., ½ H.P.S.P. & ¼ H.P.D.C.
P406B	S.P.S.T.	Open on decrease of pressure difference	
P606A	S.P.D.T.	Double throw action	8 amps.—115 volts ½ H.P.R.I.
P906A	Single Potentiometer	Graduate	Low voltage A.C. only

DIMENSIONS—Height, 8¾"; width, 9¼"; depth, 3".

RANGE AND DIFFERENTIAL—

Difference in Pressure to be Maintained		Contact Differential		Limits to Which Control May be Subjected	
Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0 lbs.	1 lb.	1½ oz.	16 oz.	0 lbs.	5 lbs.
0 lbs.	10 lbs.	¾ lbs.	6 lbs.	0 lbs.	20 lbs.
0 lbs.	45 lbs.	1½ lbs.	30 lbs.	22" vac.	85 lbs.
0 lbs.	50 lbs.	1½ lbs.	12 lbs.	2 lbs.	85 lbs.
0 lbs.	70 lbs.	4 lbs.	16 lbs.	5 lbs.	225 lbs.

WHEN ORDERING SPECIFY:

1. Type number.
2. Range. (Difference in pressure to be maintained).
3. Maximum and minimum pressures to which system will be subjected.
4. Complete details as to general application desired.

*Trade Mark

STATIC PRESSURE REGULATOR

The Static Pressure Regulator is used in conjunction with Series 60 floating damper control motors to regulate the static pressure in the discharge duct of central fan heating, ventilating, and air conditioning installations. It may also be applied in conjunction with systems of combustion regulation. Four holes provide for wall or duct mounting. Spring for adjusting pressure range; adjustable contacts and spring for differential

Type	Switch	Range	Differential	Electric Rating
P212A	S.P.D.T.	Positive Pressure: 0-2" water including diff. Negative Pressure: 0-2" water including diff.	Adjustable .05" to .75" of water for 25V. .15" to .75" of water for 115 or 230V.	1 amp.—25 volts ¼ amp.—115 volts ⅛ amp.—230 volts

DIMENSIONS—Height 7"; width, 12⅛"; depth, 5⅞". Note: One #301308C static duct head with cabinet coupling and one #301642 gallon of Finol furnished with regulator.

SPECIAL FEATURES AVAILABLE—
#301298B Outdoor duct head assembly.

WHEN ORDERING SPECIFY:
1. Type number.
2. Special features.

LIGHT DUTY DAMPER MOTORS

These small light duty motors are designed for application in conjunction with systems for zone damper or draft and check damper regulation. They are available for two position operation only, and are not satisfactory for installation where large dampers are used. Motor power unit is of the induction type. Series 20 motors are uni-directional. Series 80 motor is spring return. Adjustable crank arm standard on all types.

Types	Application	Timing	Stroke	Crank Arm			Max. Load at Extreme Radius	Max. Torque	Power Consumption	Damper Rating	Electric Rating
				Number	Min. Radius	Max. Radius					
M220A	(Series 20) Draft and check dampers	60 sec.	180° uni-directional	Two	11/16"	2½"	6 lbs.	12½ in. lbs.	8 watts	7 sq. ft.	115 V. 60 cycle transformer, power type, plate mounting standard.* Leakage type with plate or foot mounting available at no extra cost.
M26C	(Series 20) Zone damper control	60 sec.	180° uni-directional with dual control switch	One	43/64"	2 19/64"	7.8 lbs.	18 in. lbs.	8 watts		
M87A	(Series 80) Draft and check dampers	25 sec.	60° spring return	Two	1"	2 11/16"	7.5 lbs.	20 in. lbs.	20 watts lifting; 10 watts holding		

*Transformers available for odd voltages and frequencies.

DIMENSIONS—Height, 5⅛"; width, 4¼"; depth, 5⅝".

WHEN ORDERING SPECIFY:
1. Type number.
2. Voltage and frequency.
3. Specify Q564 damper linkage for M26C if required.
4. Type of transformer if other than standard.

ELECTRIC CONTROLS

MOTORS AND POWER UNITS—AUXILIARY SWITCHES

*MODUTROL MOTORS (HEAVY DUTY)

Modutrol Motor power units may be adapted through linkage mechanisms to damper and valve assemblies. Oil immersed capacitor type power units are operated directly by temperature, humidity or pressure control units.

Double ended crank shaft, size 3/8″ square, 3/8″ long. One crank arm adjustable from minimum radius of 1 9/16″ to maximum of 2 11/16″. Adjustable in steps of 22½ angular degrees for any position within full cycle. Spring for spring return type motors is included.

Type	Description	Timing	Stroke	Load Rating	†Damper Rating (sq. ft.)	Electric Rating*	Power Consumption (Lifting)
M204A	(Series 20) Two position uni-directional	½ min. 1 min. 2 min. 4 min.	180° 180° 180° 180°	40 in. lb. 80 in. lb. 108 in. lb. 108 in. lb.	25 50 70 70	Low voltage motors for A.C. only, 115 or 230 volts, 50 or 60 cycle primary transformers standard. (Odd voltage and frequency transformers available at extra cost). Line voltage motors, 115 or 230 volts, 50 or 60 cycles standard. (Odd voltage and frequency motors available at extra cost). * All motors low voltage except M405A, which is for line voltage.	22 22 15 15
M405A	(Series 40) Two position spring return	35 sec.	60°	27 in. lb.	20		18
M805A	(Series 80) Two position spring return						24
M905D	(Series 90) Proportioning spring return motor						24
M604C	(Series 60) Floating, reversible motor	½ min. 1 min. 2 min. 4 min.	160° 160° 160° 160°	40 in. lb. 80 in. lb. 108 in. lb. 108 in. lb.	25 50 70 70		15
M904E	(Series 90) Reversible proportioning motor						24
M904F	(Series 90) Reversible proportioning motor. For use where vibration is encountered. Must be used with R927C relay.						15

† Do not exceed 100 lb. net load on crank arm.
DIMENSIONS—Height, 7″; width, 5⅝″; depth, 6 3/16″.

SPECIAL FEATURES AVAILABLE:
Dual control switch for controlling extra motor available for all Series 90 motors.
Auxiliary switch for operating accessory equipment avaliable for all motors. (See Q52 Auxiliary switches for ratings).

WHEN ORDERING SPECIFY:
1. Type number.
2. Timing.
3. Voltage and frequency.
4. Special features required.

*Trade Mark

AUXILIARY SWITCHES FOR *MODUTROL MOTORS

When a Modutrol motor is operating a valve or damper, it is often necessary that an auxiliary circuit be completed as the valve or damper reaches a predetermined point in its travel. The Type Q52 auxiliary switch, which is integrally mounted with the motor, performs this function through the action of a cam-operated mercury switch. Its adjustment is arranged so that the switch, regardless of the position in which the motor is mounted, may make and break its contacts within 5 angular degrees of travel of the motor; or the differential may be broadened so that it is equal to the full travel of the motor. A single pole, double throw mercury switch is provided so that the circuit may be completed when the motor is operated in either direction, merely by choosing the proper terminals.

The Q52 is also available with two mercury switches, independently adjustable, driven by the same shaft. When two of the double-switch models of type Q52 are applied to the same motor, one mounted on the nameplate end and the other on the cover end of the motor, a four-stage multiple step operation is provided similar to that of the multiple step controllers shown on page 22.

Type	Switch	Mounting Position	Range	Differential	Electric Rating
Q52A	S.P.D.T.	Front or nameplate end of motor	May be set to operate at any point in the motor travel	Minimum of 5 angular degrees. Maximum limited only by maximum travel of motor.	S.P.D.T. switches 8 amps. @ 115 volts, 4 amps. @ 230 volts, ½ H.P.R.I., 1/10 H.P.S.P. and D.C. 115 or 230 volts; S.P.S.T. switches 10 amps. @ 115 volts, 5 amps. @ 230 volts, 1 H.P.R.I., ½ H.P.S.P. and ¼ H.P.D.C. 115 or 230 volts.
Q52B	S.P.D.T.	Back or cover end of motor			
Q52C	2 S.P.D.T.	Front or nameplate end of motor			
Q52D	2 S.P.D.T.	Back or cover end of motor			

DIMENSIONS—Height, 5¼″; width, 4″; depth, 2¾″. (Not including adaptor plate)

WHEN ORDERING SPECIFY:
1. Type number.

*Trade Mark

ELECTRIC CONTROLS
MOTORIZED VALVES

TWO POSITION TYPE

Two position heavy duty motorized valves are used extensively for controlling the flow of gases, liquids and steam. These assemblies include the Q601 linkage and are operated by the oil immersed M204 Modutrol Motor.

TYPES—SIZES—PATTERNS

Type	Motor	Linkage	Valve Body	Size	Pattern	Trim
K200B	M204A	Q601B	V575A	¼"–3"	Screwed—Bronze—Single Seat*	Bronze
K201C	M204A	Q601A	V537F	⅜"–1½"	Screwed—Bronze—Double Seat	"
K201B	"	"	V537B	½"–2"	Screwed—H. T. I.†—Double Seated	"
K201B	"	"	V537B	¾"–6"	Flange—H. T. I.†—Double Seat	"
K202A	"	"	V58A	½"–2"	Screwed—Bronze—Pilot Operated	"
K202B	"	"	V58B	2½"–3"	Screwed—H. T. I.†—Pilot Operated	"
K202C	"	"	V58C	2½"–6"	Flange—H. T. I.†—Pilot Operated	"
K203A	"	"	V538B	½"–2"	Screwed—Bronze—3-Way	"
K203A	"	"	V538B	2½"–4"	Flange—H. T. I.†—3-Way	"

*Composition Disc. †High Tensile Iron.

SPECIFICATIONS

ELECTRICAL RATING—Low voltage A.C. only. (Transformers with 115 or 230 volts, 50 or 60 cycle primary furnished as standard. Special voltages and frequencies available). For detailed specifications see M204 motors on page 15.

LINKAGE—Adjustable lift and valve position indicator standard.

Valve can be mounted in any position as long as motor shaft is horizontal.

K200B—Q601B lift adjustable from ⅜" to ¾".

SPECIAL FEATURES AVAILABLE:

Special body and trim materials for all double seated valve bodies.

Companion flanges for flanged pattern bodies at extra cost.

Auxiliary switches are available. (See page 15).

WHEN ORDERING SPECIFY

1. Type number.
2. Size.
3. Motor timing, voltage and frequency.
4. Medium to be controlled.
5. Temperature of medium to be controlled.
6. Pressure of medium to be controlled.
7. Pressure drop through valve.
8. Special features required.

NOTE: Double seated valves do not provide positive tight shut-off. Where slight leakage is not allowable, specify single seated valve bodies.

For valve capacities see pages 52, 53 and 54.

Stainless steel trim is recommended for use on double seated valves where differential pressures will exceed 70 lbs. per square inch. Stainless steel trim is also recommended for valves used on services where sand and grit may be carried in the water or fluid controlled.

PRESSURE RATINGS—

Types	Valve Size	Max. Press. Lbs. Sq. In.	Types	Valve Size	Max. Press. Lbs. Sq. In.
K200B	¼", ⅜"	125	K201B	5"	65
K200B	½"	125	K201B	6"	60
K200B	¾"	125	K202A	½"	150
K200B	1"	85	K202A	¾"	150
K200B	1¼"	60	K202A	1"	150
K200B	1½"	40	K202A	1¼"	150
K200B	2"	25	K202A	1½"	150
K200B	2½"	15	K202A	2"	150
K200B	3"	10	K202B	2½"	150
K201C	⅜"	150	K202B	3"	150
K201C	½"	150	K202C	2½"	125
K201C	¾"	150	K202C	3"	125
K201C	1"	150	K202C	4"	125
K201C	1¼"	150	K202C	5"	125
K201C	1½"	150	K202C	6"	125
K201B	½"	150	K203A	½"	150*
K201B	¾"	150	K203A	¾"	150*
K201B	1"	150	K203A	1"	90*
K201B	1¼"	150	K203A	1¼"	60*
K201B	1½"	150	K203A	1½"	40*
K201B	2"	150	K203A	2"	25*
K201B	2½"	150	K203A	2½"	16*
K201B	3"	145	K203A	3"	8*
K201B	4"	105	K203A	4"	4*

NOTE: Pressure ratings in above chart based on standard 60 second timing motor. For timings other than 60 seconds, refer to Sec. 8, Pages 22 and 23, Air Conditioning Control Manual.

*Pressure ratings shown for three-way valves refer to the maximum unbalanced pressure that can exist across the two inlets of the valve used as a mixing application. Maximum static pressures: K203, flanged, 125 lbs.; K203, screwed, 150 lbs. A complete calculation of pressure drops through the system is necessary to determine the maximum pressure differential that will exist across either seat.

ELECTRIC CONTROLS

MOTORIZED VALVES

MODULATING TYPE

Modulating Motorized Valve assemblies are applicable to all installations where the flow of gases, liquids, and steam is to be controlled. When used in conjunction with other Series 90 controllers, these valves will provide accurate modulation of flow proportionate to changes in temperature, humidity, or pressure as measured by the controller.

TYPES—SIZES—PATTERNS

Type	Motor	Linkage	Valve Body	Size	Pattern	Trim
K900B	M904E	Q601B	V575A	¼"-3"	Screwed-Bronze-Single Seated-"V" Ports*	Bronze
K901B	"	Q601A	V537B	½"-2"	Screwed-H. T. I.†-Double Seated-"V" Ports	"
K901B	"	"	V537B	¾"-6"	Flanged-H. T. I.†-Double Seated-"V" Ports	"
K903A	"	"	V538B	½"-2"	Screwed-Bronze-3-Way-"V" Ports	"
K903A	"	"	V538B	2½"-4"	Flanged-H. T. I.†-3-Way-"V" Ports	"
K910A	"	Q610B	V581A	½"-2"	Screwed-Bronze-3-Way-Throttling	"

*Composition Disc. †High Tensile Iron.

SPECIFICATIONS

ELECTRICAL RATING—Low voltage A.C. only. (Transformers with 115 or 230 volts, 50 or 60 cycle primary furnished as standard. Available for other voltages and frequencies). For detailed specifications see M904 motors on page 15.

WHEN ORDERING SPECIFY:

1. Type number.
2. Size.
3. Motor timing, voltage and frequency.
4. Medium to be controlled.
5. Temperature of medium to be controlled.
6. Pressure of medium to be controlled.
7. Pressure drop through valve.
8. Special features required.

NOTE: Double seated valves do not provide positive tight shutoff. Where slight leakage is not allowable specify single seated valve bodies.

For valve capacities see pages 52, 53 and 54.

Stainless steel trim is recommended for use on double seated valves where differential pressures will exceed 70 lbs. per square inch. Stainless steel trim is also recommended for valves used on services where sand or grit may be carried in the water or fluid controlled.

LINKAGE—Adjustable lift and valve position indicator standard. Valve can be mounted in any position as long as motor shaft is horizontal. K900B—Q601B lift adjustable from ⅝" to ¾".

SPECIAL FEATURES AVAILABLE (at extra cost):

Special body and trim materials for all double seated valve bodies.

Companion flanges for flanged pattern bodies at extra cost.

Auxiliary switches are available. (See page 15).

PRESSURE RATING—

Types	Valve Size	Max. Press. Lbs. Sq. In.	Types	Valve Size	Max. Press. Lbs. Sq. In.
K900B	¼"	125	K901B	4"	105
K900B	⅜"	125	K901B	5"	65
K900B	½"	125	K901B	6"	60
K900B	¾"	125	K903A	½"	150*
K900B	1"	85	K903A	¾"	150*
K900B	1¼"	60	K903A	1"	90*
K900B	1½"	40	K903A	1¼"	60*
K900B	2"	25	K903A	1½"	40*
K900B	2½"	15	K903A	2"	25*
K900B	3"	10	K903A	2½"	16*
K901B	½"	150	K903A	3"	8*
K901B	¾"	150	K903A	4"	4*
K901B	1"	150	K910A	½"	60*
K901B	1¼"	150	K910A	¾"	60*
K901B	1½"	150	K910A	1"	60*
K901B	2"	150	K910A	1¼"	60*
K901B	2½"	150	K910A	1½"	40*
K901B	3"	145	K910A	2"	25*

NOTE: Pressure ratings in above chart based on standard 60 second timing motor. For timings other than 60 seconds, refer to Sec. 8, Pages 22 and 23, Air Conditioning Control Manual.

*Pressure ratings shown for three-way valves refer to the maximum unbalanced pressure that can exist across the two inlets of the valve used as a mixing application. Maximum static pressures: K903, flanged, and K910, 125 lbs.; K903, screwed, 150 lbs. A complete calculation of pressure drops through the system is necessary to determine the maximum pressure differential that will exist across either seat.

ELECTRIC CONTROLS

MOTORIZED VALVES

ELECTRIC RADIATOR TYPE

Packless type Motorized Radiator Valves of the two position type are available for controlling the flow of water or steam to one or two-pipe systems of direct radiation. Available for either low or line voltage service, they are frequently used in offices, school rooms and auditoriums where control of individual radiators is required.

Valve bodies are brass. Straight through non-offset, straight through offset and angle pattern bodies available. Composition disc for tight shut-off. Power unit employs special shaded pole induction motor.

Type	Voltage	Power Consumption	Electric Rating	Pressure Rating		Timing
				Body Size	Pounds per Square In.	
V205A	(Series 20) Low	15 watts	Low voltage A.C. only. (Trnsformer with 115 volts, 50 or 60 cycles primary furnished standard. Odd voltages and frequencies.	¾" 1" 1¼" 1½" 2"	35 20 15 12 10	1 min. open or close
V605A	(Series 60) Line	8 watts	115 volts, 60 cycle standard (Available for odd voltages and frequencies at extra cost).			

SPECIAL FEATURES AVAILABLE:

Dual switch for operating additional radiator valves. (Four valves maximum for any one thermostat). High pressure valves at extra cost (¾", 80 lbs., 1", 60 lbs., 1¼", 50 lbs.).

WHEN ORDERING SPECIFY:

1. Type number.
2. Size.
3. Pattern of valve body.
4. Voltage and frequency.
5. Medium to be controlled.
6. Temperature of medium to be controlled.
7. Pressure of medium to be controlled.
8. Special features required.

NOTE: V205A valves may be ordered less transformers if central transformer is to be used.

MOTORIZED BUTTERFLY VALVE

The Motorized Butterfly Valve is regularly used with a low voltage thermostat to control the flow of hot water on gravity or forced circulation hot water heating plants. The power unit for this valve is of the capacitor type—type M204A for 2-position service, type M904E for modulating service. An auxiliary switch can be supplied to control the operation of a second K208A valve or the primary control on a burner. Valve pattern is straight through, brass screwed.

Type	Voltage & Frequency	Motor Timing	Power Consumption	Max. Press. Lbs. Sq. In.	Max. Temp.	Size	Face to Face	Height Overall	Height Above Pipe Center
K208A and K908A	(External transformer furnished) 115 volt, 50 or 60 cycle standard. (Available for 230 volt, 50 or 60 cycle at no extra cost). 115 or 230 volt, 25 cycle at extra cost.	30 sec. 60 sec. 120 sec. 240 sec.	(K208) 22 watts (K908) 15 watts	20	250° F.	1½" 2" 3" 4" 5" 6"	3" 3½" 4 11/16" 5¼" 5 11/16"	10 25/32" 11 1/16" 11 27/32" 13 3/16" 14 9/16"	9 11/16" 9 11/16" 9 29/32" 10 17/32" 11 1/16"

SPECIAL FEATURES AVAILABLE (at extra cost):

Auxiliary switch: Mercury switch type Q52B: One S.P.D.T. switch. Q52D: 2 S.P.D.T. switches. Electrical rating 5 amps. 115 volts, 2½ amps. 230 volts.

WHEN ORDERING SPECIFY:

1. Type number.
2. Size.
3. Voltage and frequency.
4. Special features required.

ELECTRIC CONTROLS

SELF-CONTAINED VALVES — THERMOMETERS

THE MODUSTAT*

The Modustat is a self-contained radiator valve and affords modulating control for individual radiators on steam, vapor, or vapor vacuum systems. This control unit is suitable for use on two-pipe systems only, and is available for application on either exposed or concealed radiators.

All Modustats are provided with both automatic and manual control ranges. Available with manual adjustment knob or tamper-proof key mechanism.

Type	Description	Range	Maximum Operating Pressure	Size (Both Types)	Capacity (Sq. Ft. Radiation)
V505A	Rigid element for exposed radiation	60 to 80° F. standard	10 lbs. per sq. in.	½"	80
V506A	Flexible element for concealed radiation (Flexible tubing length—36" standard)			¾"	100
				1"	120

DIMENSIONS—Height, (less element) 6"; width, 6"; depth, 2½".

SPECIAL FEATURES AVAILABLE:
Remote right angle or vertical adjustment handle at extra cost. Specify length from cap of Modustat to outside of cabinet.

WHEN ORDERING SPECIFY:
1. Type number.
2. Size.
3. Special features required.

*Trade Mark

TYPE W59 THERMOMETER

This remote bulb thermometer is equipped with a universal mounting bracket which allows the face of the thermometer to point to the right, left or straight ahead, and also to point at any angle between vertical and horizontal. This desirable feature combined with the wide red non-freezing liquid column permits temperature reading from a distance of several feet. Adaptable to wall or duct mounting.

The W59B, designed for insertion in water pipes or tanks, is similar to the W59A except it is equipped with a protecting copper well and it is not furnished with a mounting clip.

SPECIFICATIONS

MODEL
W59A Remote Bulb Thermometer—flexible element.
W59B—Remote Bulb Thermometer—flexible element—copper protecting well for liquids.

FINISH—Black Kristo-Krak.
RANGE:—30 to +180° F. only.

ELEMENT—5 ft. capillary tubing only.
CAPSULE SIZE—2⅝"x11/32".
DIMENSIONS—Height, 9" (scale length 6½"); width, 2 11/32"; depth, 11/16". Depth with adjustable bracket 3¼".

WHEN ORDERING SPECIFY
1. Type number.

ELECTRIC CONTROLS

RELAYS

Magnetic relays are available for applications wherever it is desirable to amplify the switching capacity of a controller unit. Relays are available with either low or line voltage control circuits. Many types of contact arrangements are available to allow complete coordination of these relays with other control units.

SPECIFICATIONS

Type	Control Circuit	LOAD CIRCUIT					Cabinet Size (inches overall)
		No. of Poles	Switching Action	Relation to Supply Circuit	Resistance Load	Motor Load	
R12A	Series 10	2	double throw	separate	10 amps.–115 V. A C.—5 amps–230 V. A.C.	1 H.P. A.C.	6 5/8x6 1/4x3 7/8
R14A	Series 10	1	double throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A C.	7 1/2x9x5
R15A (D.C.)	Std. 2-wire line voltage	1	single throw	separate	5 amps.–115 V. D.C.—2 1/2 amps.–230 V. D.C.	1/2 H.P. D.C.	6 5/8x4 3/8x3 1/2
R19A	Series 10	1	single throw	common	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R19C	Series 10	1	single throw	common	10 amps–20 V.	———	6 5/8x4 3/8x3 1/2
R39A	Series 30	1	single throw	common	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R48A	Std. 2-wire line voltage	1	single throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R48B	Std. 2-wire line voltage	1	double throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R48B (D.C.)	Std. 2-wire line voltage	1	double throw	separate	1/2 amp.–115 V. D.C.—1/4 amp.–230 V. D.C.	———	6 5/8x4 3/8x3 1/2
R48C	Std. 2-wire line voltage	2	double throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R48C (D.C.)	Std. 2-wire line voltage	2	double throw	separate	1/2 amp.–115 V. D.C.—1/4 amp.–230 V. D.C.	———	6 5/8x4 3/8x3 1/2
R88A	Std. 2-wire low voltage	1	single throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R88B	Std. 2-wire low voltage	1	double throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R88C	Std. 2-wire low voltage	2	double throw	separate	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1 H.P. A.C.	6 5/8x4 3/8x3 1/2
R92B	Series 90	1	double throw	separate	10 amps.–115 V. A.C.—5 amps–230 V. A.C.	1 H.P. A.C.	7 1/2x9x5
R132A	Series 10	2	single throw	common	10 amps.–115 V. A.C.—5 amps.–230 V. A.C.	1/2 H.P. A.C. (Each Contact)	6 5/8x4 3/8x3 1/2
R182A	Series 10-20-80	1	single throw	common	10 amps.-115 V. A.C.—5 amps.-230 V. A.C.	1 H.P. A.C.-115 V.- 1 1/2 H.P. A.C.- 230 V.	5 1/4x4 1/16x2 5/8
R182B	Series 10-20-80	1	double throw	separate	10 amps.-115 V. A.C.—5 amps.-230 V. A.C.	1 H.P. A.C.-115 V.- 1 1/2 H.P. A.C.- 230 V.	5 1/4x4 1/16x2 5/8
R182C	Series 10-20-80	2	double throw	separate	10 amps.-115 V. A.C.—5 amps.-230 V. A.C.	1 H.P. A.C.-115 V.- 1 1/2 H.P. A.C.- 230 V.	5 1/4x4 1/16x2 5/8
R927C	Used only to control M904F motor.						

ELECTRICAL RATING— All relays with Series 10 or other 3-wire Low voltage control circuits except R14B and R19C are provided with integral transformers with 115 volts, 60 cycle primary circuits. Relays for odd voltages and frequencies are available.

CURRENT CONSUMPTION—R48 and R88: 7 volt amps.

WHEN ORDERING SPECIFY:
1. Type number.
2. Voltage and frequency.

ELECTRIC CONTROLS
WEATHERSTATS

T14A Weatherstat

WEATHERSTAT CONTROL PACKAGES

The Weatherstat Control System has an outside type of thermostat for use in controlling temperatures in buildings or zones that are large enough so that control from an inside thermostat is impractical. It is unique in that it reacts to all weather factors which affect heat losses from a building or zone. These factors are: 1. Outside Temperature; 2. Wind velocity; 3. Wind direction; and, 4. Solar Radiation.

The Weatherstat Control Systems are applicable to forced hot water, steam or vapor heating plants fired by stoker, oil or gas burner.

Even temperature in the building or zone is maintained throughout all outdoor conditions because the Weatherstat meters steam or hot water in proportion to the heat loss.

Simplicity of the system means reduced installation and wiring cost, ease of adjustment and service-free operation. The operation of both the Weatherstat systems (Zone and Direct) will be greatly improved if the radiators are properly orificed. Orifice plates are available on special order. Neither Weatherstat Control System is recommended for gravity type hot water heating system.

Summer-Winter Hot Water Control can also be arranged, providing an ample supply of domestic hot water at constant temperature where required: — for full particulars consult the nearest Minneapolis-Honeywell Representative.

The listed Weatherstat Control Packages do not include a Weatherstat Heater Control, which varies according to the type of heating plant the system is to control, and therefore, must be ordered separately.

W101A Control Panel

WEATHERSTAT DIRECT CONTROL PACKAGES

The Weatherstat Direct Control System is ideal for buildings too large to be satisfactorily controlled from an inside thermostat but small enough to be controlled as a single zone. For example, small apartment buildings, hotels, and clubs can all be heated more economically and with greater comfort under a Weatherstat Direct Control System.

This system substitutes the Weatherstat for the conventional inside thermostat to control the automatic firing device. Required for the system are the Weatherstat itself, a Control Panel housing all the necessary accessories, and a heater control to regulate the operation of the Weatherstat Heater.

The Series 10 Weatherstat is connected to the Weatherstat Panel and through the relays and the manual switch in the panel is connected directly to a Series 10 or Series 20 primary control. The primary control can be an oil burner relay, a gas valve or stoker relay. The manual switch provides a positive "off", a continuous "on", or places the Weatherstat in control of the primary control. The standard limit controls are used with the primary control, and their selection depends upon the type of burner which is used.

Weatherstat Heater Control

THE WEATHERSTAT ZONE CONTROL SYSTEM

The Weatherstat is very adaptable as a zone control system. The building is zoned according to its heating zones, and each zone is controlled by its own weatherstat and steam valve system.

The same neat control panel used in the direct system is furnished as a part of each zone installation. This panel includes a line switch, "On-Off-Automatic" manual switch, and a pilot light to show when the valve is open.

Zone valves for the Weatherstat system are made up of three units—a motor, a linkage, and a valve body.

These Weatherstat Zone Control Systems can be furnished with Modulating Control for large buildings. The Modulating Weatherstat Zone Control System is usually part of a zoned system. Because of the fact that it is a continuous flow system, the steam supply will be throttled during mild conditions, and complete orificing of all radiators is necessary in order to insure proper distribution. This system provides for "on-off" or two position control during mild weather. "On-off" control during mild weather insures proper steam distribution at those times when most modulating systems have difficulty in properly distributing their heating effect, even when radiators are carefully orificed.

SPECIFICATIONS

Y155A CONTROL PACKAGE (T14A Weatherstat, and W101A Control Panel with Time Switch)—For use with steam, vapor or forced hot water heating systems; oil, gas or stoker fired. Provides for automatic night shutdown and automatic morning pick-up. 115 or 230 volt, 60 cycle standard.

Y155B CONTROL PACKAGE (T14A Weatherstat and W101B Control Panel)—For use with steam, vapor or forced hot water heating systems; oil, gas or stoker fired. Provides for manual night shutdown and manual morning pickup. Will provide automatic night shutdown and morning pickup when used with R154 Timerelay on stoker jobs, 115 or 230 volt, 50-60 cycle standard.

WHEN ORDERING SPECIFY

1. Type of Weatherstat Heater Control; consult the nearest Minneapolis-Honeywell representative.
2. Type of burner (stoker, oil or gas).
3. Control package (Y155A or Y155B). Specify voltage and frequency.
4. If primary burner controls are not furnished with the burner they can be ordered separately.

ELECTRIC CONTROLS

STEP CONTROLLERS AND ACCESSORY EQUIPMENT

MULTIPLE STEP CONTROLLER

Mercury Switch Type

Mercury Switch Type Step Controllers are available with 5 to 10 mercury switches in any desired combination of S.P.S.T. and/or S.P.D.T. switching action. These controllers are built up in the desired combination complete on a panel with M904E Modutrol motor, but the motor must be specified separately. Likewise, if a cabinet for housing the controller is desired, it must be specified separately.

Cut-in and cut-out points of each are separably adjustable to any point within the 160° rotation of motor shaft. The minimum differential between cut-in and cut-out points is 5 angular degrees of motor shaft rotation.

SPECIFICATIONS

MODELS

S416A—5 mercury switches in any desired combination of S.P.S.T. or S.P.D.T. switching (less motor and cabinet).

S416F—10 mercury switches in any desired combination of S.P.S.T. or S.P.D.T. switching (less motor and cabinet).

SWITCH RATINGS—

S.P.S.T.—10 amps. 115 volts, 5 amps. 230 volts; 1 H.P. A.C., ¼ H.P.D.C.

S.P.D.T—8 amps. 115 volts, 4 amps. 230 volts; ½ H.P. A.C., 1/6 H.P.D.C.

DIMENSIONS—

Controller—Height, 8½"; length, 18"; width, 7½".

Cabinet (Q150A)—Height, 11"; length, 24"; depth, 8".

WHEN ORDERING SPECIFY

1. Type number.
2. Switching action desired, that is, number of S.P.S.T. and S.P.D.T. switches.
3. Voltage and frequency of transformer for M904E motor.
4. Motor timing.
5. Q150A cabinet, if desired.

POTENTIOMETER TYPE CONTROLLER

Type S906 potentiometer step controllers are available with potentiometers arranged for sequence or simultaneous operation of Series 90 modulating equipment. When ordering specify sequence desired, timing of motor, and voltage and frequency.

FOUR STAGE STEP CONTROLLER

Mercury Switch Type

Consists of standard M904E motor equipped with one Q52C and one Q52D auxiliary switch.

The cut-in and cut-out points of each switch can be set at any point within the 160° angular travel of the motor with a minimum possible differential of 5 angular degrees between cut-in and cut-out points.

WHEN ORDERING SPECIFY (see Page 15).

1. Type number of motor, timing, voltage and frequency.
2. Type numbers of auxiliary switches.

M-H CON-TAC-TOR MERCURY SWITCHES

C603 and H168
Mercury Switches

The mercury switches used in M-H controls have long been recognized for their dependability. Pure, free-flowing mercury completes the circuit between sealed-in electrodes. The glass chamber is filled with a pure inert gas, eliminating any possibility of oxidized or dirty contacts. No moving parts but the mercury.

Mercury switches have outstanding ability to handle heavy loads on direct current as indicated under D.C. ratings. We recommend them in lieu of open contact devices for all applications requiring direct control of D.C. motors.

Mercury switch controls with adjustable differential must be properly leveled to secure correct operation. For details, see M-H installation and instruction sheets furnished with each control.

ELECTRIC CONTROLS
TIME CONTROLLERS—SWITCHES

TIME CONTROLLERS

This line voltage timing device was designed primarily to control the operation of attic fans, store lights, or other electrical equipment where the current supply is to be turned off after some predetermined interval.

The timer may be set to close the circuit for any period of time from one half to eleven hours, merely by twisting the knob on the front of the timer until the desired time interval appears on the dial. A twist of the knob in the opposite direction will turn off the current supply at any time, should this become necessary. A separate manual lever is included which may be used to manually tilt the mercury switch to the "on" position. The reverse acting model S403B is similar to the S403A except that it is arranged to open the circuit for a period of from one half to eleven hours.

The important features of this device include the well known Con-Tac-Tor mercury switch, and facility for mounting so that either concealed or exposed wiring may be used. This latter feature makes the timer easily adaptable for use on either old or new installations.

Mounts on standard switch outlet box. Has knockout for wire mould or similar exposed circuit. Finished in silver bronze.

Type	Contact	Timing Limits	Electric Rating
S403A	Makes for an adjustable period	½ hour to 11 hours	10 amps.—115 volts 5 amps.—230 volts 1 H.P.R.I., ½ H.P.S.P., ¼ H.P.D.C.
S403B	Opens for an adjustable period		

DIMENSIONS—Height, 5½"; width, 3¼"; depth, 3".

WHEN ORDERING SPECIFY
1. Type number.

DA-NITE TIME SWITCH

This device is an electrically operated time switch designed to automatically "break" one circuit and "make" another at a predetermined time.

The Time Switch finds many applications in the temperature control field. Warehouse systems, for example, can provide lowered night temperature or complete night shutdown.

Typical among its many other uses are control of lighting, flood lights, displays and yard lighting. Many other types of electrical equipment requiring daily S.P.S.T. or S.P.D.T. switching action can be readily operated by the S610A.

Distinctive features of the S610A include the synchronous self-starting Telechron motor, the well-known Con-Tac-Tor mercury switch, hinged cover, simplified setting, ease of mounting and two separate conduit knockouts. This latter feature permits control of either low or line voltage loads.

TYPE
S610A Da-Nite Time Switch. S.P.D.T. for low or line voltage loads.

VOLTAGE AND FREQUENCY—115 volt, 60 cycle standard. Other A.C. voltages and frequencies available at extra cost.

ELECTRICAL RATING—8 amps. at 115 volts, 4 amps. at 230 volts; ½ H.P.R.I., 1/6 H.P.S.P. and D.C.

SWITCHING INTERVAL—(Time interval between switching operations). Minimum, 1 hour; maximum, 23 hours. One complete switching cycle every 24 hours.

FINISH—Black Kristo-Krak.

CASE DIMENSIONS—Height, 6¼"; width, 3¾"; depth, 4½".

WHEN ORDERING SPECIFY
1. Model number.
2. Voltage and frequency.

No. 20348

UNIT HEATER SWITCH

A 3-position line-voltage utility switch designed for manual control of unit heaters. Affords a double-pole double-throw switching action, and is rated for 10 amps. at 125 volts, 5 amps at 250 volts. Dimensions: height, 4 5/16", width, 2 9/16", depth, 2".

ELECTRIC CONTROLS

MANUAL AND UTILITY SWITCHES

TOGGLE SWITCHES
Line or Low Voltage

20271—S.P.S.T., 12 amp. at 125 volts.
20272—D.P.S.T., 12 amp. at 125 volts.
20273—S.P.D.T., 6 amp. at 125 volts.
20103A—D.P.D.T., 3 amp. at 110 volts. (illustrated).
20104A—S.P.3 T.—6 amp. at 24 volts. (three-position).
20105A—4 P.D.T.—3 amp. at 110 volts. **(rotary).**

INDICATING PLATES
(Round—2¼″ Diameter)
For Toggle Switches

20106—Three position, marked "auto," "open," "closed." Center position neutral. (illustrated).
20108—Marked "on," "off."
20129—Marked 'manual," "auto."
20130—Marked "open," "closed."
20170—Marked "Summer," "Winter."
20189—Marked "Day," "Night."

For Potentiometer Switches

20133—Graduated through 180°, marked "open," "closed."

POTENTIOMETER SWITCHES
Low Voltage, 3-wire

30112A—One 135 ohm Potentiometer.
20171A—Two 135 ohm Potentiometers, gang.
20172A—Three 135 ohm Potentiometers, gang. (illustrated).
20173A—One 25-300 ohm Rheostat (2-wire).
The above switches are available with 3″ leads—specify if required.
Q34A—One 30112A Potentiometer and one 30111 (D.P.D.T.) Toggle mounted in surface box. (Illustrated below).

SWITCH MOUNTINGS
Surface Boxes with Cover

4″x4″x2½″—Black Kristo-Krak. (Similar to Q34A box).
35301C—Plain cover.
35301D—Cover drilled for single switch.
35301E—Box with six-screw terminal block and cover drilled for one switch.

WALL PLATES AND ADAPTER
Black Kristo Krak

20136A—4½″x2¾″ for std. switch box. Drilled for single switch.
20137B—4½″x6⅜″ for 3-gang switch box. Drilled for 2 switches.
20138B—Same as 20137B, except drilled for 3 switches.

UTILITY SWITCHES

The Utility Switch is a mechanically operated switching device for the control of two or three wire line or low voltage electrical circuits—external lever arm projects 1¼″. Two ½″ knockouts are provided. Tension spring on switch mechanism can be adjusted.

Type	Lever Arm	Action When Arm is Raised	Switch	Electric Rating	Connections
S45A	Projects from left side of case	Close	S.P.S.T.	10 amps.—115 volts 5 amps.—230 volts 1 H.P.R.I., ½ H.P.S.P., ¼ H.P.D.C.	Two ½″ knockouts
S45B	Projects from right side of case				
S45C	Projects from left side of case	Open			
S45D	Projects from right side of case				

CASE DIMENSIONS—Height, 4″; width, 4″; depth, 2½″.

WHEN ORDERING SPECIFY: 1.Type number.

ELECTRIC CONTROLS

TRANSFORMERS

MASTER TRANSFORMERS

Power type transformers of high capacity are available on order for all voltages and frequencies. These are supplied with taps for 20, 24 and 28 volts; legs on case for mounting; conduit connections for primary and secondary.

WHEN ORDERING SPECIFY
1. Primary voltage and frequency.
2. Capacity required in volt-amperes.

LEAKAGE TYPE TRANSFORMERS

For Mounting on 4-inch Outlet Box
Open Secondary Connections

Type Number	Capacity in Volt Amps.	Primary Voltage and Cycles	Open Secondary Voltage	Dimension Above 4" Outlet Box Cover	Shipping Weight
Q76A1K	14	115-60	25	3½"	2.5#
Q76A1L	14	230-60	25	3½"	2.5#
Q76A1M	14	115-25	25	4"	3.8#
Q76A1B	14	230-25	25	4"	3.8#
Q76A1S	14	115-50	25	3½"	3#
Capacities shown are for 100% power factor; reduce Capacity by 25% for 50% power factor.					
Q77A1K	27	115-60	25	4"	3.8#
Q77A1L	27	230-60	25	4"	3.8#
Q77A1M	27	115-25	25	5"	5.5#
Q77A1B	27	230-25	25	5"	5.5#
Capacities shown are for 100% power factor; reduce Capacity by 40% for 50% power factor.					

WHEN ORDERING SPECIFY
1. Type number. 2. Primary voltage and frequency.

POWER TYPE TRANSFORMERS

For Mounting on 4-inch Outlet Box.
Open Secondary Connections.

Type Number	Capacity in Volt Amps.	Primary Voltage and Cycles	Open Secondary Voltage	Dimension Above 4" Outlet Box Cover	Shipping Weight
Q71A1K	20	115-60	20	2½"	2.5#
Q71A1L	20	230-60	20	2½"	2.5#
Q71A1M	20	115-25	20	3"	3.5#
Q71A1B	20	230-25	20	3"	3.5#
Q72A1K	40	115-60	25	2¾"	2.5#
Q72A1L	40	230-60	25	2¾"	2.5#
Q73A1M	40	115-25	25	5"	5#
Q73A1B	40	230-25	25	5"	5#

For Mounting on 4-inch Outlet Box. Open Secondary Connections. 3 Ampere Fuse in Secondary.

Type Number	Capacity in Volt Amps	Primary Voltage and Cycles	Open Secondary Voltage	Dimension Above 4" Outlet Box Cover	Shipping Weight
Q72B1K	40	115-60	25	2¾"	2.5#
Q72B1L	40	230-60	25	2¾"	2.5#
Q73B1M	40	115-25	25	5"	5.5#
Q73B1B	40	230-25	25	5"	5.5#
Q74B1K	50	115-60	18, 20, 24	4½"	3.8#
Q74B1L	50	230-60	18, 20, 24	4½"	3.8#
Q74B1M	50	115-25	18, 20, 24	6¼"	6#
Q74B1B	50	230-25	18, 20, 24	6¼"	6#

For Surface Mounting. Open Secondary Connections.
Three Ampere Fuse in Secondary

Type Number	Capacity in Volt Amps.	Primary Voltage and Cycles	Open Secondary Voltage	Overall Height	Shipping Weight
Q72B2K	40	115-60	25	3"	2.5#
Q72B2L	40	230-60	25	3"	2.5#
Q73B2M	40	115-25	25	3¼"	5.5#
Q73B2B	40	230-25	25	3¼"	5.5#

For Mounting on 4-inch Outlet Box. Conduit Secondary Connections With Leads

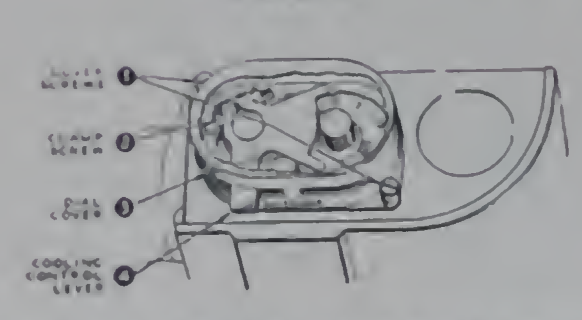
Type Number	Capacity in Volt Amps.	Primary Voltage and Cycles	Open Secondary Voltage	Dimension Above 4" Outlet Box Cover	Shipping Weight
Q71A3K	20	115-60	20	2½"	2.5#
Q71A3L	20	230-60	20	2½"	2.5#
Q71A3M	20	115-25	20	3"	3.5#
Q71A3B	20	230-25	20	3"	3.5#
Q72A3K	40	115-60	25	2¾"	2.5#
Q72A3L	40	230-60	25	2¾"	2.5#
Q73A3M	40	115-25	25	5"	5.5#
Q73A3B	40	230-25	25	5"	5.5#
Q74A1K	100	115-60	18, 20, 24	4½"	3.8#
Q74A1L	100	230-60	18, 20, 24	4½"	3.8#
Q74A1M	100	115-25	18, 20, 24	6"	6#
Q74A1B	100	230-25	18, 20, 24	6"	6#

WHEN ORDERING SPECIFY
1. Type number.
2. Primary voltage and frequency.

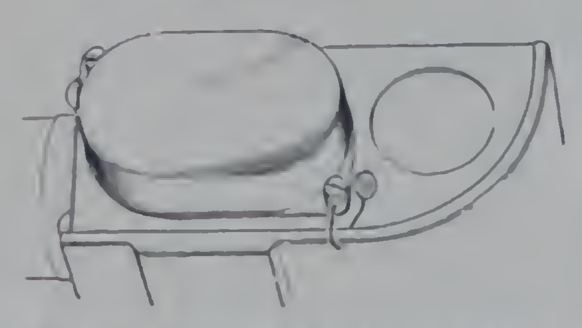
•M-H SNAP SWITCH PRESSURE CONTROLS

LOW PRESSURE CONTROL

P420B



Use of Cold Control on Cut-out



Adjustment shield in place

Use the P420 to operate refrigeration equipment from suction pressure. Adaptable to all systems using non-corrosive refrigerant. Three-point mounting ensures accuracy.

Standard features include: Tamperproof shield for adjustment dials; Cold control for limited change of either cut-out or cut-in; Capillary pressure connection; Extra reverse acting terminal.

For cases, coolers or walk-in boxes, apply lever to cut-out adjustment. Setting of cut-in then remains undisturbed to ensure defrosting.

For water or beverage coolers, lever may be applied to cut-in adjustment. Setting of cut-out then remains undisturbed to prevent freeze-up.

Reverse acting terminal closes on pressure fall. Useful to control compressor bypass valves, two speed motors, to ground low voltage ignition circuits or for alarm circuits.

Complete instructions & specifications, M-H Form 95-1124.

RANGE—22" vac. to 65#.

DIFFERENTIAL—7#—Cut-in and cut-out are separately adjustable.

ELECTRICAL RATING—A.C.—¾ H.P. @ 115 V., 1 H.P. @ 230V., 1 amp. @ 440-550V.
D.C.—1.5 amp. @ 32V., .2 amp. @ 115V., .1 amp. @ 230V.

P420B—.(Direct reading Scales). Wt. 1¾ lbs.

HIGH PRESSURE CUTOUT

P422A

For high pressure cut-out duty on all non-corrosive refrigerant systems, use the P422A or P422B. Three-point mounting ensures accuracy.

Standard features include: Capillary pressure connection; Extra reverse acting terminal for alarm circuit or low voltage ignition control; Fully adjustable range; Adjustable recycling time.

Complete instructions & specifications, M-H Form 95-1126.

RANGE—100# to 240#. Differential 25# to 45#. Both adjustable.

ELECTRICAL RATING—A.C.—¾ H.P. @ 115V., 1 H.P. @ 230V., 1 amp. @ 440-550V.
D.C.—1.5 amp. @ 32V., .2 amp. @ 115V., .1 amp. at 230V.

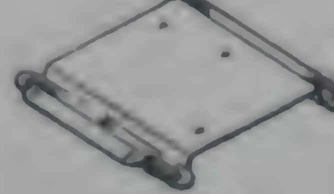
P422A—............Wt. 1½ lbs.

P422B—.....(With Manual Reset) Wt. 1½ lbs.

Semi-universal Mounting Brackets For P420, P421 or P422.

34244A

No. 34244A for vertical mounting using 4 bolts on 1⅛"x3⅛" centers or 2 bolts on 2¼" to 3⅛" centers. Includes 3 screws to mount control on bracket.



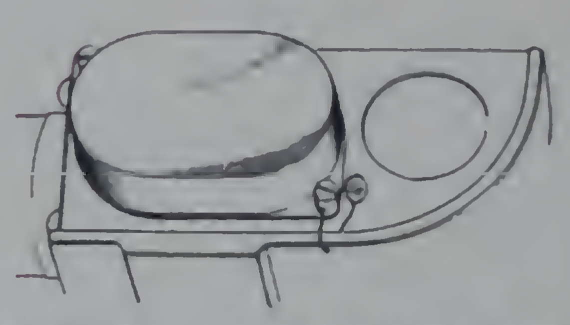
32928A

No. 32928A for mounting using 4 holes spaced 3⅛"x2⅟₁₆" to 3½", or to replace L413, L414, P400 or P401 controls. Includes 3 screws to attach control to bracket.

DUAL HIGH AND LOW PRESSURE CONTROL

P421B

Use of Cold Control on Cut-out



Adjustment shield in place

Use the P421 when cut-out from excessive head pressure is required in addition to operation of refrigeration equipment from suction pressure. Adaptable to all systems using non-corrosive refrigerants. Three-point mounting ensures accuracy.

Standard features include: Tamperproof shield for adjustment dials; Cold control for limited change of either cut-out or cut-in; Capillary pressure connections; Extra terminal for reverse action; Adjustable recycling time for high-pressure cutout.

For cases, coolers or walk-in boxes, apply lever to cut-out adjustment. Setting of cut-in then remains undisturbed to ensure defrosting of coils.

For water or beverage coolers, lever may be applied to cut-in adjustment. Setting of cut-out then remains undisturbed to prevent freeze-up.

Reverse acting terminal useful to ground low voltage ignition systems or for alarm circuits.

Complete instructions & specifications, M-H Form 95-1125.

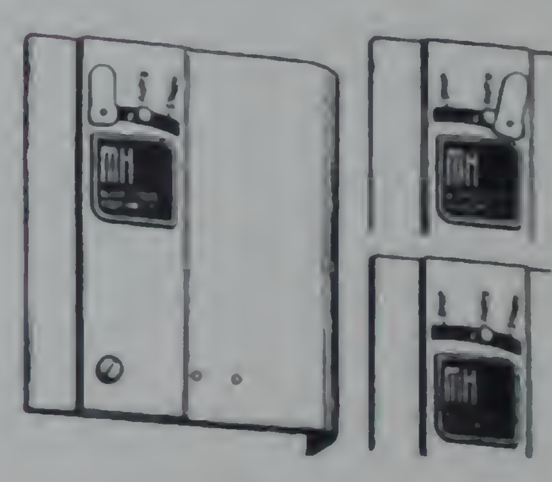
RANGE—Low side-22" vac. to 65#.
High side, adjustable-100# to 240#. Differential 25# to 45#.

DIFFERENTIAL—7#—Cut-in and cut-out separately adjustable.

ELECTRICAL RATING—A.C.—¾ H.P. @ 115V., 1 H.P. @ 230V., 1 amp. @ 440-550V.
D.C.—1.5 amp. @ 32V., .2 amp. @ 115V., .1 amp. @ 230V.

P421B—..(Direct reading Scales). Wt. 2#

MANUAL START-STOP ASSEMBLY



Q66A

Replaces standard cover on P420 or P421 to provide manual start or stop, or both. Can be added on existing installations. Useful for manual start on milk or beverage coolers, or for manual stop on systems used intermittently.

Complete instructions & specifications, M-H Form 95-1266.

Q66A—.............Wt. ¼ lb.

COLD LOCATION RECYCLER

For use with P420 or P421.

Q89A

For use with P420 or P421 Pressure Controls to start compressor when located in a low ambient temperature that sometimes prevents cutting in from suction pressure. In extremely cold locations a small electrical heater (not furnished) mounted inside control increases speed of operation. Can be used with W55A Relay or with W90A. Is easily added to existing installations.

Bimetal element operates switch of P420 or P421.

Complete instructions & specifications, M-H Form 95-1284.

Q89A—.............Wt. ¼ lb.

•M-H POLARTRON▲ SYSTEM ACCESSORIES

SIMULTANEOUS ADJUSTMENT ATTACHMENT

The Q155 installed on the P420 or P421 permits the user of refrigeration equipment to easily readjust the pressure control to operate at widely different temperatures.

Such readjustment requires that the cut-out pressure setting be changed less than the cut-in pressure setting in order to reduce the operating differential at the lower temperature. For the first time this is possible with the Q155 because of the unique separate adjustment feature of the P420 and P421.

Where special conditions require the Q155 may be adjusted to affect the cut-in and cut-out pressure equal amounts in the conventional manner.

Complete instructions and specifications M-H Form 97-741

RANGE—Changes cut-in setting up to a maximum of 20 lbs. Adjustable to change cut-out setting up to a maximum of either 20 lbs., 16 lbs. or 13 lbs.

Q155A.............Wt. ¼ lb.

POLARTRON SYSTEM RELAY

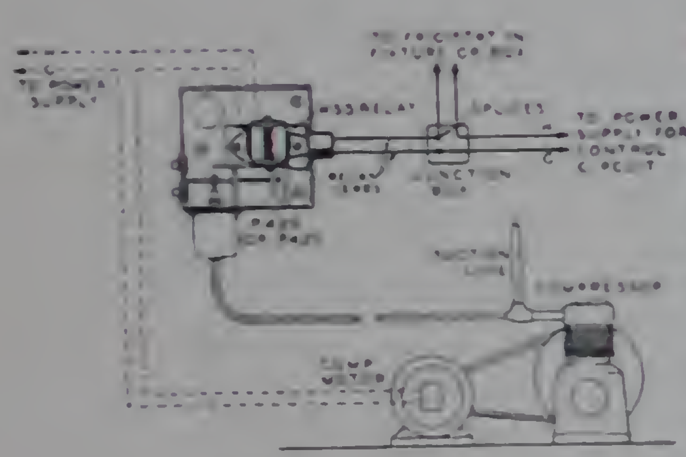
Use with P420 or P421 and Remote Thermostat.

W55A

Add a W55 Relay controlled by a Frigistat in the main fixture to a P420 or P421 on any "above freezing" system.

Relay operates switch in P420 or P421 Pressure Control. Can be added to new controls or to controls already on existing installations.

"Polartron System of Frost-Free Constant Cold"—Provides accurate regulation of fixture temperature at all times and assures positive defrosting of the cooling coils each cycle.



W55A Relay
Schematic Diagram

Adjustments for week-end, holiday, and seasonal changes are entirely eliminated as the Polartron system automatically responds to changing loads, producing constant temperature and humidity with improved efficiency.

The schematic diagram above shows simplicity of adding W55A Relay on P420 or P421 Pressure Control controlled by a fixture thermostat.

Complete instructions & specifications, M-H Form 95-1157

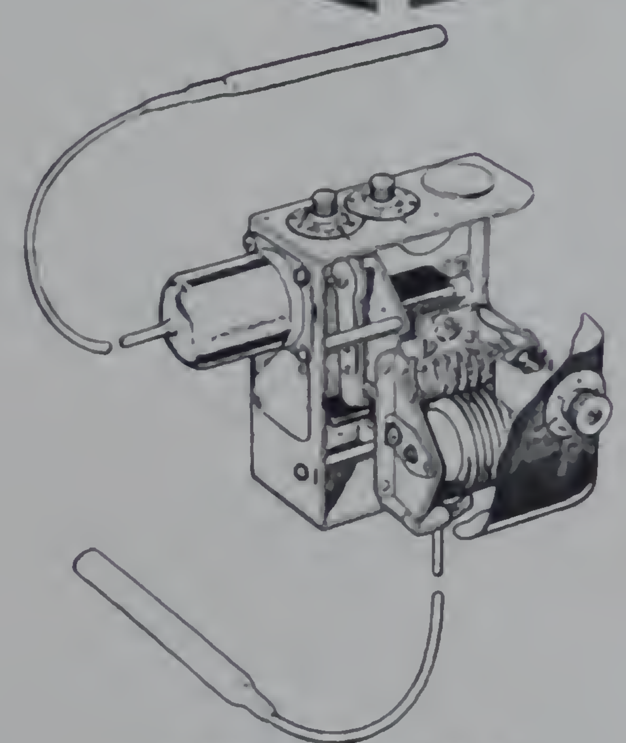
W55A—..(115-230V., 50-60 cycles). Wt. 1 lb.

W55A—........(115-230V., 25 cycles) Wt. 1 lb.

Specify voltage and frequency.

POLARTRON SYSTEM TEMPERATURE CONTROLLER

W90A



W90A Mounted
on Polartron

The W90A is a remote bulb temperature controller which, when mounted on a P420 or P421 Pressure Control, provides the M-H "Polartron System of Frost-Free Constant Cold".

Install a W90A on any "above freezing" system with temperature bulb placed in the fixture for better control with completely automatic defrosting. Cold control dial is incorporated in this unit.

The W90A Temperature Controller has no electrical contacts of its own—a lever operated by the bellows opens the switch of the pressure control at all times when the temperature in the fixture is sufficiently low. It is designed for applications where the complete Polartron system unit can be mounted close enough so that the temperature element will reach the fixture.

Complete instructions & specifications, M-H Form 95-1288.

RANGE—30-60°, inside adjustment. External cold control—6°.

W90A— ....Wt. 1 lb.

8′ Capillary standard at above prices.

•M-H HEAVY DUTY, MERCURY SWITCH PRESSURE CONTROLS

LOW-PRESSURE & DUAL-PRESSURE CONTROLS

L414A

The L414 employs a heavy-duty mercury type switch for operation of the refrigeration equipment from suction pressure. Switching action is provided by two pools of mercury which flow together, thus accounting for the ability of this switch to handle extremely heavy loads. For use on non-corrosive refrigerants only. Has direct reading range and differential scales. Differential adds to the cut-out or range setting. Pressure connection is ¼″ S.A.E. with flare nut furnished.

The L413A is the same as L414A except with high pressure cut-out.

RANGE—Low Side—22″ vac. to 35#. (2# to 50# at extra cost). High Side—150 to 180#, 185 to 220#. Adjustable.

DIFFERENTIAL—Low Side—Maximum 25# to 30#. Minimum 3#. High Side—30 and 50#, respectively. Not adjustable.

ELECTRICAL RATING—A.C.—1½ H.P. @ 115V., 2 H.P. @ 230V. D.C.—¾ H.P. @ 115V., 1 H.P @ 230V.

L413A—.......High Pressure Cut-Out.

L414A—.............Wt. 3¼ lbs.

L414B—..(With Reverse Acting Switch) Wt. 3¼ lbs.

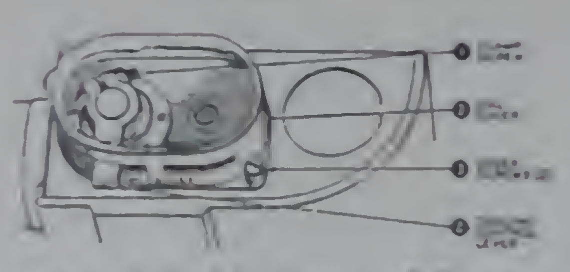
L414A / **L414B** } 2-50# range, specify if needed. Wt. 3¼ lbs.

Complete instructions & specifications, M-H Form 95-1205.

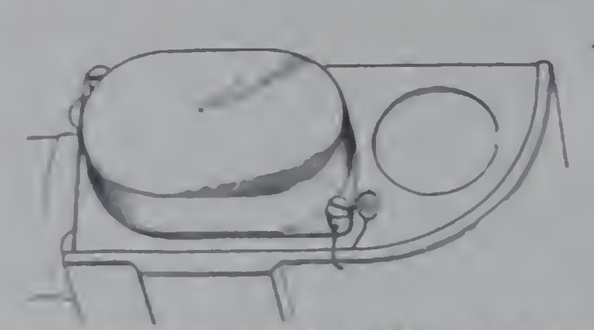
•M-H SNAP SWITCH TEMPERATURE CONTROLLERS

TEMPERATURE CONTROLLER

L480B



Use of Cold Control Lever



Adjustment shield in place

Use the L480 to operate refrigeration equipment from temperature wherever a remote-bulb device is required. Provided with a single-turn, direct-reading adjustment dial. Three-point mounting ensures accuracy.

Standard features include: Tamperproof shield for adjustment dial; Cold control; Internal differential adjustment; Extra terminal for reverse action.

Use the tamperproof shield wherever the customer must be prevented from adjusting the control. Use the cold control lever where seasonal adjustment is required—as for example, on beverage coolers. The reverse-acting terminal closes on temperature fall and is useful to control compressor bypass valves, two-speed motors, to ground low-voltage ignition circuits or for alarm circuits.

Complete instructions & specifications, M-H Form 95-1244.

RANGES—3/8"x4" bulb -50° to -10° F., -20° to +20° F., -10° to +40° F., 0° to 50° F., 30° to 70° F., and 65° to 95° F. (Specify which).

DIFFERENTIAL—3° to 12° F.. Adjustable

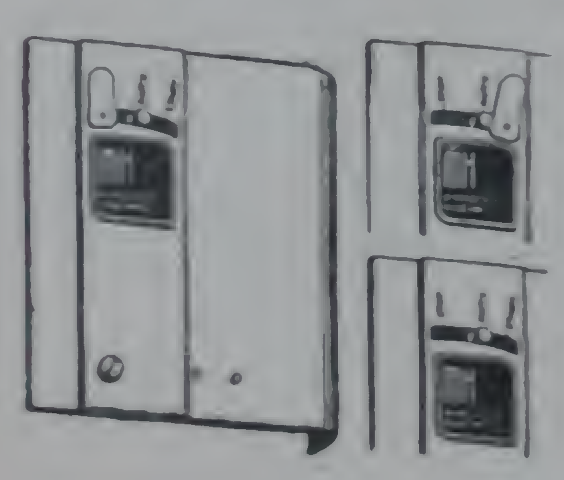
ELECTRICAL RATING—A.C.—3/4 H.P. @ 115V., 1 H.P. @ 230V., 1 amp. @ 440-550V.
D.C.—1.5 amp. @ 32V. .2 amp. @ 115V. .1 amp. @ 230V.

L480B— (Direct Reading Scale). Wt. 1 3/4 lbs.

L480B {With milk cooler bulb 1 1/16"x 14 1/2"; ranges 30-70 or 65-95 only. Specify when desired.} Wt. 1 3/4 lbs.

5' Capillary standard at above prices.

MANUAL START-STOP ASSEMBLY



Q66A

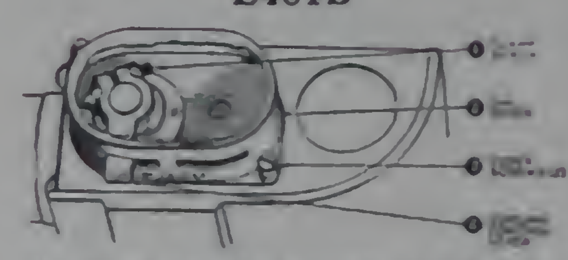
Replaces standard cover on L480 or L481 to provide manual start or stop, or both. Can be added on existing installations. Useful for manual start on milk or beverage coolers, or for manual stop on systems used intermittently.

Complete instructions & specifications, M-H Form 95-1266.

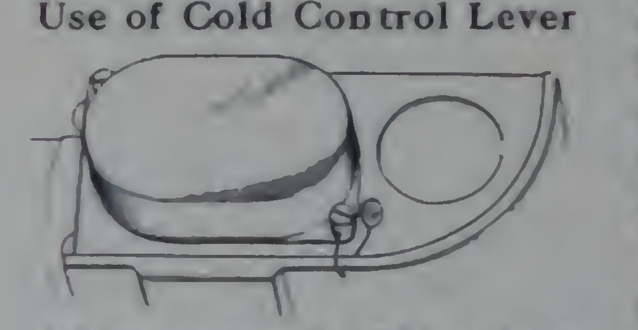
Q66A—............Wt. 1/4 lb.

DUAL TEMPERATURE AND HIGH PRESSURE CONTROLLER

L481B



Use of Cold Control Lever



Adjustment shield in place

Use the L481 when cut-out from excessive head pressure is required, in addition to operation of refrigeration equipment from temperature, as measured by a remote bulb. Adaptable to all systems using non-corrosive refrigerants. Three-point mounting ensures accuracy.

Standard features include: Tamperproof cover for adjustment dials; Cold control; Capillary pressure connection; Extra terminal for reverse action; Adjustable recycling time for high-pressure cutout.

Use the tamperproof shield where customers must be prevented from adjusting control, or use cold control lever where a limited adjustment is required, such as seasonal adjustment of beverage coolers. Reverse-acting terminal is useful for grounding low-voltage ignition circuits or for alarm circuits.

Complete instructions & specifications, M-H Form 95-1245.

RANGES—Temperature (3/8"x4" bulb) -50° to -10° F., -20° to +20° F., -10° to + 40° F., 0° to 50° F., 30° to 70° F., and 65° to 95° F. (Specify which)
HPCO—100-240# adjustable.

DIFFERENTIAL—3° to 12° F., adjustable.
HPCO—25-45# adjustable.

ELECTRICAL RATING—A.C.—3/4 H.P. @ 115V., 1 H.P. @ 230V., 1 amp. @ 440-550V.
D.C.—1.5 amp. @ 32V., .2 amp. @ 115V., .1 amp. @ 230V.

L481B—(Direct Reading Scale). Wt. 2 lbs.

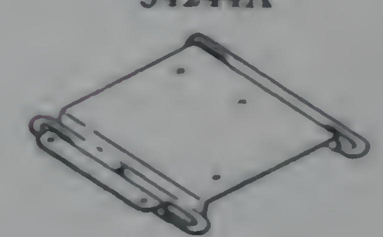
L481B {Milk cooler bulb 1 1/16"x14 1/2" ranges 30-70 or 65-95 only, specify if needed.} Wt. 2 lbs.

5' Capillary standard at above prices.

Semi-universal Mounting Brackets For L480 or L481.

34244A

No. 34244A for vertical mounting using 4 bolts on 1 1/8"x3 1/8" centers or 2 bolts on 2 1/4" to 3 1/8" centers. Includes 3 screws to mount control on bracket.



32928A

No. 32928A for mounting using 4 holes spaced 3 1/16"x2 7/16" to 3 1/2", or to replace T413, T414, L426 or L427 controls. Includes 3 screws to attach control to bracket.

THE M-H TYPE QS611 CON-TAC-TOR SNAP SWITCH

QS611
Snap Switch

All Snap Switch Temperature and Pressure Controls employ the QS611 Con-Tac-Tor Snap Switch. Produced after years of research, these switches operate by a toggle mechanism and do not require magnets. Hence they will operate in any position and can be used where vibration cannot be avoided.

The initial pressure on the contacts is immediately increased as the switch operates to effectively prevent contact bounce, thereby preventing arcing and contact deterioration. Together with complete elimination of vanishing contact pressure, this action assures long life.

In case of accidental damage, these switches can be easily replaced without the necessity of recalibrating the controls.

Three switch models are available. Sold for replacement only.

QS611A—Used in TA420
QS611B—Used in L480, L481 and P422A.
QS611C—Used in P420, P421 and P422B.

•M-H LIGHT DUTY, MERCURY SWITCH TEMPERATURE CONTROLLERS

TEMPERATURE CONTROLLER

L426A

Contains a mercury switch to provide 2-wire line voltage switching for operation of the refrigerating machine. Designed for controlling temperatures in rooms, freezer cabinets, display cases, liquid coolers, and the like where a room type thermostat is not practical.

External lugs provide convenient 3-point mounting to ensure leveling and easy installation. Has direct reading scale on side showing both Fahrenheit and Centigrade.

Complete instructions & specifications, M-H Form 95-1206.

RANGES— -50° to +20° F. 3/8"x4" bulb, or -20° F. to +50° F. 1/2"x4" bulb standard. 15° to 90° F. 11/16"x14 1/2" bulb; -80° to -10° F., or -130° to -70° F., 3/8"x4" bulb at extra cost. (Specify which).

DIFFERENTIAL—3° F. to 20° F. adjustable.

SPECIAL FEATURES AVAILABLE:
Special Mercury Switch with narrow fixed differential in Ranges +15 to +90° F., -130° to -70° F., and -80 to -10° F. Rating 1/12 H.P.R.I., 1/20 H.P.S.P. and D.C. . . . . Add $2.00 List Extra

ELECTRICAL RATING—A.C.—3/4 H.P. @ 115-230V.
D.C.—1/4 H.P. @ 115-230V.

L426A— . . . . Wt. 3 1/4 lbs.

L426A— With milk cooler bulb 11/16"x14 1/2"; 15-90° range only. Wt. 3 1/4 lbs.

L426A— -80 to -10 and -130 to -70 ranges. Wt. 3 1/4 lbs.

5' Capillary standard at above prices.

WIDE RANGE TEMPERATURE CONTROLLER

L626B

This controller is similar to the L426 Refrigeration Temperature Controller, but the main scale is divided into two parts to obtain its unusually wide range.

The switch is single pole, double throw, making it possible to use the control on either heating and cooling applications or on both.

Useful for control of low and high temperature test cabinets, laboratory boxes and altitude chambers.

Complete instructions & specifications, M-H Form 95-1328

RANGES— -100 to +50° F. or +40 to +210° F., standard (specify which). Equivalent Centigrade ranges marked on same scale plate.

DIFFERENTIAL—2 1/2° at mid-scale, non-adjustable.

ELECTRICAL RATING—1 Amp at 115 V., 1/2 Amp at 230 V.
1/20 H.P.R.I., 1/20 H.P.S.P. or 115 or 230 V. A.C.

L626B— Range -100 to +50° F. (Bulb 4"x 1/2"). Wt. 3 1/4 lbs.

L626B— Range +40 to +210°F. (Bulb 14"x11/16"). Wt. 3 1/4 lbs.

5' Capillary standard at above prices.

3-WIRE TEMPERATURE CONTROLLER
CONTACTS CLOSE SIMULTANEOUSLY

L426B

Contains a 3-wire line voltage mercury switch which closes three contacts simultaneously on rise in temperature. Designed for use where two or more thermostats start the same compressor and at the same time open individual liquid valves or for any similar application.

External lugs provide for convenient 3-point mounting to ensure leveling and easy installation. Has direct reading scale on side of case showing both °F. and °C.

Complete instructions & specifications, M-H Form 95-1206.

RANGES— -50° F. to +20° F., 3/8"x4" bulb, or -20° F. to +50° F., 1/2"x4" bulb, standard. 15° to 90° F., 11/16"x14 1/2" bulb at extra cost. (Specify which).

DIFFERENTIAL—3° F. to 20° F., adjustable.

ELECTRICAL RATING—(Each circuit).
A.C.—1/12 H.P. @ 115-230V., 4 amps. @ 20V., 2 1/2 amps. @ 115V., 1 1/4 amps. @ 220V.
D.C.—1/20 H.P. @ 115-220V., 4 amps. @ 20V., 2 1/2 amps. @ 115V., 1 1/4 amps. @ 220V.

L426B— . . . . Wt. 3 1/4 lbs.

L426B— (With milk cooler bulb, 11/16"x14 1/2"; 15-90° F. range only. Wt. 3 1/4 lbs.

5' Capillary standard at above price.

•M-H HEAVY DUTY, MERCURY SWITCH TEMPERATURE CONTROLLERS

TEMPERATURE CONTROLLER

T414A

Contains a heavy duty mercury switch to provide 2-wire line voltage switching for operation of the refrigerating machine Designed for direct control of temperature in larger sized rooms, freezer cabinets, display cases, liquid coolers and the like where a room type thermostat is not practical.

External lugs provide for convenient 3-point mounting to ensure leveling and easy installation. Has scale plate on side marked Low and High and calibrated at midpoint of scale.

Complete instructions & specifications, M-H Form 95-1201.

RANGES— -60° to +10° F., 3/8"x4" bulb or -10° F. to +50° F., 1/2"x4" bulb standard. 15 to 90° F., 11/16"x14 1/2" bulb at extra cost. (Specify which).

DIFFERENTIAL—3 1/2° to 13° F., adjustable.

ELECTRICAL RATING—A.C.—1 1/2 H.P. @ 115V., 2 H.P. @ 230V.
D.C.—3/4 H.P. @ 115V., 1 H.P. @ 230V.

T414A— . . . . Wt. 3 1/2 lbs.

T414A— (With milk cooler bulb 11/16"x14 1/2"; 15-90° range only). Wt. 3 1/2 lbs.

T414A— Special switch for 1/2° non-adjustable differential—1 amp. @ 230V., 2 amps. @ 115V. A.C. or D.C.—(Specify when needed). Add

5' Capillary standard at above prices.

S.P.D.T. TEMPERATURE CONTROLLER

T614A

Contains a 3-wire line voltage heavy duty mercury switch for Single Pole Double Throw switching action. Designed for operation of valves with separate opening and closing coils, two speed motor control, alarm circuit use, etc. Can be used for either line or low voltage applications where a room type thermostat is not practical.

External lugs provide for 3-point mounting to insure leveling and easy installation. Has scale plate on side marked Low, High, and calibrated at mid-point of scale.

Complete instructions & specifications, M-H Form 95-1201.

RANGES— -50° F. to + 10° F., 3/8"x4" bulb or -10° F. to +50° F., 1/2"x4" bulb standard, 15 to 90° F., 11/16"x14 1/2" bulb at extra cost. (Specify which).

DIFFERENTIAL—2 1/2° F. to 13° F., adjustable.

ELECTRICAL RATING—A.C.—1/3 H.P. @ 115-230V.
D.C.—1/6 H.P. @ 115-230V.

T614A— . . . . Wt. 3 1/2 lbs.

T614A— (With milk cooler bulb 11/16"x14 1/2"; 15-90° range only). Wt. 3 1/2 lbs.

5' Capillary standard at above prices.

▲ Trade Mark.

REFRIGERATION CONTROLS

•M-H WALL TYPE THERMOSTATS

HEAVY DUTY FRIGISTAT▲
WITH SNAP ACTING SWITCH

TA420A

A new horizontal type, snap acting, heavy duty thermostat for room temperature control of refrigerating machines. New horizontal style permits greater circulation of air around the sensitive vapor filled bellows. Modern, attractive cover has easy to read thermometer and harmonizing window for reading scale setting.

Knob for adjusting scale setting can be detached and used as key for locking cover to prevent unauthorized tampering or setting. Switch has extra reverse acting contact, for control of capacity reduction valves, alarms or similar uses.

Standard mounting plate facilitates wiring and installation on "roughed in" horizontal box.

Can be used in the Polartron System of control.

Complete instructions & specifications, M-H Form 95-1235.

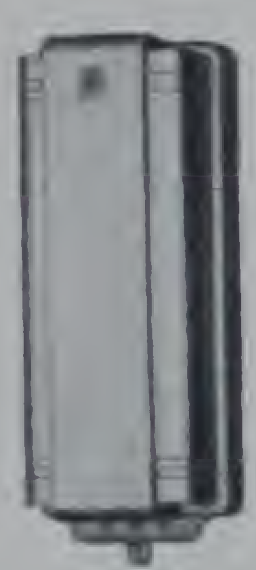
RANGE: 35° F. to 65° F. standard. Optional 25° F. to 55° F. or 55° F. to 85° F. and centigrade equivalents at no extra cost. Specify which if other than standard.

DIFFERENTIAL: 1° to 4° F., adjustable.

ELECTRICAL RATING—A.C.—¾ H.P. @ 115V., 1½ H.P. @ 230V. 10 amps. @ 115-230V. for commercial refrigeration. On comfort cooling, load should be reduced to one-half to produce comfortable differential.
D.C.—.1 amp. @ 230V., .2 amps. @ 115V., 1.5 amps. @ 32V., 2 amps. @ 24V.

TA420A—..........Wt. 1½ lbs.

LIGHT DUTY, SNAP ACTING, COOLING THERMOSTAT



T44C

A light duty, snap-acting, cooling thermostat designed for line or low voltage use. Has bimetal element and open contacts for S.P.S.T. switching action. Is not affected by variations in altitude. Temperature setting lever moves on a graduated scale plate at bottom of control. Standard model not equipped with thermometer.

Complete instructions & specifications, M-H Form 95-1134.

RANGE: 29° to 61° F.

DIFFERENTIAL: 1½° to 6° F., adjustable.

ELECTRICAL RATING—A.C.—5 amps. @ 115V., 2½ amps. @ 230V. ¼ H.P. @ 115-230V.
D.C.—15 volt amperes.

T44C—..............Wt. ¾ lb.

T44C—Wt. ¾ lb.
(With two magnets for transportation work).

FRIGISTAT▲—MERCURY SWITCH TYPE

T420A

Long accepted for use primarily as room type thermostats, these Frigistats are equipped with vapor filled bellows and mercury switches designed for a variety of functions. Can be used in line or low voltage circuits for pilot duty to control refrigerating machines in meat boxes, florist cabinets, walk-in boxes, etc. All parts are plated to protect them from corrosion.

Can be used in the Polartron System.

Complete instructions & specifications, M-H Form 95-1135.

RANGE: 30° F. to 65° F. Centigrade equivalent at no extra cost.

DIFFERENTIAL—Approximately 3° F.

ELECTRICAL RATING—A.C.—2 amps. @ 115V., 1 amp. @ 230V.
D.C. Same ampere rating.

Note: For 3 contact switches the combined load, if more than one is controlled should not exceed the ratings given above.

T420A—(2-wire switch, makes contact on temperature rise). Wt. 1½ lbs.

T420C—Wt. 1½ lbs.
(3 contact switch, makes contact on temperature rise).

T420D—Wt. 1½ lbs.
(3 contact switch, makes contact on temperature fall).

T420E—Wt. 1½ lbs.
(3 contacts close in sequence on temperature rise).

HEAVY DUTY AIRSWITCH▲

T491A

A heavy duty, bimetal actuated, mercury switch type thermostat for cooling. Used widely in storehouses, lockers, cooler rooms, florists cabinets, factories and for general space cooling. Operating point is not affected by variations in altitude.

Has lugs for convenient 3-point mounting on a wall or panel surface. Temperature setting is easily made on front of control and can be locked when desired.

Complete instructions & specifications, M-H Form 95-1087.

RANGE: 15° to 95° F. standard. -10 to +70° F. at extra cost.

DIFFERENTIAL: 3° to 8° F., adjustable.

ELECTRICAL RATING—A.C.—8 amps. @ 115V., 4 amps. @ 230V. 1/3 H.P. @ 115-230V.
D.C.—8 amps. @ 115V., 4 amps. @ 230V. 1/6 H.P. @ 115-230V

T491A—............Wt. 2 lbs.

T491A—Wt. 2 lbs.
(Special range— -10° F. to +70° F.).

T491C—Wt. 2 lbs. .... 15 -95°.. -10 +70°.

T691A—Wt. 2 lbs.
(Has S.P.D.T. Switch rated @ ½ H.P.A.C.).

Pneumatic Controls

MINNEAPOLIS-HONEYWELL Offers

A new degree of Accuracy and Responsiveness

Far reaching basic improvements in pneumatic control equipment have been achieved by Minneapolis-Honeywell engineers. These improvements provide control results far superior to anything previously possible with air operated controls.

Consider carefully the following points of superiority.

The Gradustat* — not an ordinary thermostat

• **APPEARANCE—**
The Gradustat expresses modern architectural feeling—the product of Henry Dreyfus, a leading exponent of structural and product design.

• **GREATER EFFICIENCY—**
The Gradustat is a non-leak type of thermostat. It has no leakport, and therefore uses air only when it is changing the position of an air motor or valve. This reduces the quantity of air required and, therefore, the power required to produce air pressure, by at least 30%.

• **GREATER SENSITIVITY—**
The horizontal mounting of the Gradustat provides for the free flow of air over the low-mass, super-sensitive bellows, because there is no restriction to the flow of air except the grill work in the cover. This free flow of air makes the Gradustat extremely sensitive to rapid changes in temperature.

• **TRUE GRADUATION—**
In the Gradustat, there is a straight line relation between temperature at the thermostat and the air pressure in the branch line between zero pounds and 15 pounds, which means perfect graduation, as compared to a leak type thermostat, where the relation of temperature to branch line pressure takes the form of an S-curve.

*Trade Mark

The Gradutrol System

The Gradutrol System differs from conventional pneumatic systems through the use of a small pneumatic relay for positive positioning of damper motors and valves.

• OPERATION—

The operation of the Gradutrol System is extremely simple. A small diaphragm within the motor relay is influenced by the air pressure in the branch line to the thermostat. This diaphragm is balanced by a spring which is operated by the motor arm or valve stem. Position of the motor determines spring tension. Double ports within the relay control the feeding or bleeding of air to and from the motor. When a change in pressure at the thermostat takes place, sufficient air is fed to or bled from the motor to cause it to assume a new position, air from the main line being available at 15 lbs. pressure.

In the conventional pneumatic system the air pressure in the motor is the same as the air pressure in the branch thermostat line. It is thus a variable pressure depending upon the demand of the thermostat. This variable pressure established by the thermostat is balanced by the motor spring and load. Variation in this pressure requires new loadings rather than new definite positions.

With the Gradutrol System a definite pressure established by the thermostat requires that the motor assume a very definite position. The motor is capable of producing full power in either direction in order to assume the position called for by the thermostat. Pressures in the motor from zero to 15 lbs. are available at all times, depending upon the force required or the motor to assume its proper position.

• TRUE GRADUATION—

means accurate positioning. The uneven action and the drift in position with changing load, frequently found on conventional pneumatic systems, is entirely eliminated thru the definite positioning of the Gradutrol Motor.

• INFINITE POSITIONS—

mean hair line control. Sticky valves and jumpy motors—an inherent result of friction in the conventional pneumatic system—are impossible in the Gradutrol System. The number of positions which may be assumed by the valves or dampers is limitless between full open and full closed with the Gradutrol System.

• INSTANT POWER—

means definite movement for the smallest control impulse. For even a slight change of as little as ½ of 1% of the total range, the Gradutrol Motor will produce the maximum power that the motor or valve can attain. This feature is of particular importance when the control valve or damper is just starting to open as it is then that friction or pressure will ordinarily prevent proper positioning.

• SIMPLE CONSTRUCTION—

means low cost and easy installation. The Gradutrol Relay may be installed on any MH pneumatic control valve or damper motor whether on new control installations or on equipment already in service. The simplicity of this remarkable device makes it possible for every installation to enjoy the advantages it offers at a very nominal difference in cost

PNEUMATIC CONTROLS

THERMOSTATS

ROOM GRAD-U-STATS*

Pneumatic Gradustats are non-bleed type, actuated by vapor filled bellows and are graduate acting with an adjustable throttling range. A very simple adjustment permits changeover from a direct to a reverse acting instrument. Their horizontal construction allows free flow of air over the sensitive bellows and yet provides ample protection against tampering and dust.

TYPES

T0900A—Two pipe, Single temperature Grad-U-Stat for heating or cooling.

T0900B—Two pipe, Da-Nite Grad-U-Stat for use with a remote switch to provide lowered night, holiday, or week-end temperatures.

T0900C--Three pipe, Submaster, cooling Grad-U-Stat for compensated control. Room temperature may be automatically raised from 5 to 15 degrees above normal with rising outdoor temperature.

T0900D—Two pipe, Summer-Winter Grad-U-Stat. Direct acting in winter, reverse acting in summer. Separate adjustments for summer and winter setting, (changeover by changing main pressure).

SPECIFICATIONS

SCALE RANGES—T0900A: 35 to 65°, 60 to 85°, and 70 to 95° F. T0900B: 60 to 85° F. T0900C: 60 to 85° and 70 to 95° F. T0900D: 65 to 85° F.

PRESSURE RANGE—T0900A and C: 0 to 15 lbs. air pressure, T0900B and D: 0 to 13 lbs. and 0 to 17 lbs.

THROTTLING RANGE—Adjustable from 3 to 10° F. for direct acting; 3 to 6° F. for reverse acting.

SCALE MARKINGS—Every 2 degrees.

TYPE OF MOUNTING—Standard Flush mounting in wall. Special: For surface mounting.

ADJUSTMENT MEANS—Key type standard. External knob available.

COVER—Locking type.

THERMOMETER—Available with or without.

FINISH—Standard: Silver bronze. Special: Available at extra cost.

*Trade Mark

OVERALL DIMENSIONS — Grad-U-Stat: Height, 3"; width, 4⅞"; depth, 1¾". Wallbox: Height, 2¼"; width, 4½"; depth, 3".

FITTINGS—Flexible connectors in wall box or copper tubing in surface box. Copper tubing in wall box at extra cost.

SPECIAL FEATURES (at extra cost):
External adjusting knob. Heavy Duty Guard.

WHEN ORDERING SPECIFY:

1. Type number.
2. Scale range.
3. Adjustment means—key or external knob.
4. Finish.
5. With or without thermometer.
6. Special features required.

Note: Order fittings separately.

ROOM GRAD-U-THERM*

The pneumatic Grad-U-Therm is a bleed type, bimetal actuated, graduate room thermostat which incorporates the requirements of the typical pneumatic room thermostat.

TYPES

T0901A—Two pipe, single temperature, direct acting.

T0901B—Like T0901A except reverse acting.

SCALE RANGE—55 to 85° F. only.

PRESSURE RANGE—0 to 15 lbs.

THROTTLING RANGE—4° non-adjustable.

TYPE OF MOUNTING—Flush wall.

ADJUSTMENT—External dial with concealed locking device.

*Trade Mark.

FINISH—Standard: Silver Bronze.

DIMENSIONS—Height, 4⅜"; width, 1¾"; depth, 1⅞".

WHEN ORDERING SPECIFY:

1. Type number.
2. #13108 fittings for new construction.
3. Complete details if for replacement.

PNEUMATIC CONTROLS

THERMOSTATS

INSERTION GRAD-U-STAT*

The Insertion Grad-U-Stat is a non-bleed type remote bulb controller for duct mounting. They are similar to and contain all the features of room type Grad-U-Stats, but are actuated by a bellows connected to a vapor filled capillary tubing and bulb.

TYPES

L0900A—Two pipe, Single temperature Grad-U-Stat for heating or cooling.
L0900B—Three pipe, Submaster, cooling Grad-U-Stat for compensated control. Duct temperature may be automatically raised from 5 to 15 degrees above normal with rising outdoor temperature.
L0900C—Two pipe, Summer-Winter Grad-U-Stat. Direct acting in winter, reverse acting in summer. Separate adjustments for summer and winter settings, (changeover by changing main pressure).

SPECIFICATIONS

SCALE RANGES—L0900A: 10 to 40°, 35 to 65°, 60 to 85°, 70 to 95°, and 80 to 120° F. L0900B: 35 to 65°, 60 to 85° and 70 to 95° F. L0900C: 65 to 85° F.

PRESSURE RANGES—L0900A and B: 0 to 15 lbs. air pressure. L0900C: 0 to 13 lbs. and 0 to 17 lbs.

THROTTLING RANGE—Adjustable from 3° to 15° for direct acting; 3° to 10° for reverse acting.

SCALE MARKINGS—Every 2 degrees.

TYPE OF MOUNTING—Standard: Surface mounting. Special: Flush mounting.

ADJUSTMENT MEANS — Standard: External knob. Special: Key type.

COVER—Locking type.

FINISH—Standard: Silver bronze.

OPERATING ELEMENT—Vapor filled capsule, tubing and bellows.

ELEMENT—Standard: 5 ft. Special 10 ft.

*Trade Mark

CAPSULE MATERIAL—Copper.

CAPSULE SIZE — ½" in diameter by approximately 12½" in length for standard range. (60°-85° F.)

PRESSURE FITTINGS—½" pipe size.

DIMENSIONS—Grad-U-Stat: Height, 3"; width, 4⅞"; depth, 1¾". Mounting Box: Height, 3⅛"; width, 5"; depth, 1 15/16".

FITTINGS — Copper tubing inside mounting box. Box tapped for ⅛" pipe. Brass unions provided.

SPECIAL FEATURES AVAILABLE—
Separable wells: Copper, mild steel, stainless steel and monel.
Wall box for flush mounting (#1362 Fittings) (Same as Room Thermostat).
Mild Steel Capsule (at extra cost).

WHEN ORDERING SPECIFY:
1. Type number.
2. Scale range.
3. Adjustment means.
4. Finish.
5. Special features required.
6. Element length.

Type L092

INSERTION THERMOSTATS

Pneumatic Insertion Thermostats are graduate acting instruments for duct mounting, employing a sensitive rod and tube element. They may also be immersed in liquids when provided with proper wells.

TYPES

L092C—Graduate direct acting, one-pipe.
L092D—Graduate reverse acting, one-pipe.
L0901A—Graduate, direct acting, two-pipe. Master type, used as compensator in pneumatic compensated control system.
L0901B—Same as L0901A except reverse acting.
L0902A—Graduate direct acting, three-pipe (two-pipe control). Submaster type used as controller in pneumatic compensated system. May be adjusted to raise control point 25 to 150°.
L0902B—Same as L0902A except reverse acting.

SPECIFICATIONS

RANGE AND DIFFERENTIAL—

TYPE	TEMPERATURE RANGE	THROTTLING RANGE
L092	20 to 180° F. and 120 to 280° F.	3° F.
L0901	−20 to 120° F.	15 to 75° F.
L0902	−20 to 120° F.	5 to 20° F.

PRESSURE RANGE: 0 to 15 lbs.

SPECIAL RANGES AVAILABLE—L092C and D: —40° to +120° F., at extra cost.

OPERATING ELEMENT—Rod and tube.

ADJUSTMENT MEANS—L092: External knob, L0901 and L0902: Inside cover.

MOUNTING MEANS—½" male pipe thread.

ELEMENT LENGTH—14½".

DIMENSIONS—L092: Height, 4¼"; width, 3¼"; depth, 3¾". L0901: Height, 4⅝"; width, 2"; depth, 3". L0902: Height, 5⅜"; width, 4"; depth 2¾".

WHEN ORDERING SPECIFY:
1. Type number. 2. Range.

PNEUMATIC CONTROLS
THERMOSTATS

REMOTE BULB TEMPERATURE CONTROLLER

L097A Temperature Controllers are air-operated remote bulb instruments designed to provide throttling control of either direct or reverse acting motors, valves, relays, etc.

A change-over link provides a simple means for changing the Controller from a direct acting type to a reverse acting type or vice versa as required.

TYPE

L097A Temperature Controller—Throttling type, one pipe, direct or reverse acting, remote bulb controller.

SPECIFICATIONS

TEMPERATURE RANGE—0 to 70°, 60 to 100°, 65 to 140°, 105 to 220°, 160 to 280°, 240 to 385°, 370 to 530°, 510 to 700° F. (Equivalent centigrade ranges shown on same scale).

THROTTLING RANGE—Adjustable 1% to 10% of temperature range.

OPERATING ELEMENT—Vapor filled bellows, tubing and bulb.

CAPILLARY TUBING—5 ft. smooth ⅛" O.D. capillary tubing standard. Copper standard for ranges up to 385° F., monel standard for higher ranges up to 700° F. Available in lengths up to 30 ft., with copper, mild steel or monel capillary tubing and bulb on special order at extra cost. Armored tubing may also be furnished (at extra cost.

BULB—Copper standard for ranges up to 385° F., monel standard for higher ranges up to 700° F. (Available in monel or mild steel on special order at extra cost). Sizes 14½"x11/16" for ranges 0 to 70° F., 60 to 100° F. and 65 to 140° F. 4"x½" for higher ranges up to 700° F.

PRESSURE FITTING—¾" pipe size for ranges 0 to 70° F., 60 to 100° F. and 65 to 140° F., ½" pipe size for higher ranges.

STANDARD FITTINGS—⅛" "T" restriction, restriction key, and ⅛" union.

CASE MOUNTING—Surface only.

CASE DIMENSIONS—Height, 7"; width, 5"; depth 3⅛".

ADJUSTMENT MEANS—External knob on top of case for setting control point. External slotted screw for setting throttling range.

SPECIAL FEATURES AVAILABLE:
External slotted screw for setting control point.
Separable Wells—Copper, mild steel, st. steel and monel.
Filter, reducing valve and air supply gauge.

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.
3. Tubing length and material, also whether plain capillary or armored tubing is required.
4. Special features required.

DIFFERENTIAL THERMOSTAT

The differential thermostat reacts to a change in the difference in temperature between two points rather than in a change at a particular temperature setting. Thus it is used as a controller for maintaining a constant differential temperature in a wide variety of applications.

TYPE

L0903A—Graduate, one pipe, direct or reverse acting.

SPECIFICATIONS

RANGE OF DIFFERENCE IN TEMPERATURE TO BE MAINTAINED: 2 to 40°.

THROTTLING RANGE: 1 to 6°.

OPERATING ELEMENT—two opposed vapor filled bellows with remote bulbs and tubing.

TUBING—Standard: 5 ft. copper. Special 10 ft., 20 ft.

BULBS—11/16" Diameter; Length 12½" for 5 and 10 ft. 17½" for 20 ft. copper.

SCALE—Blank—to be marked as desired.

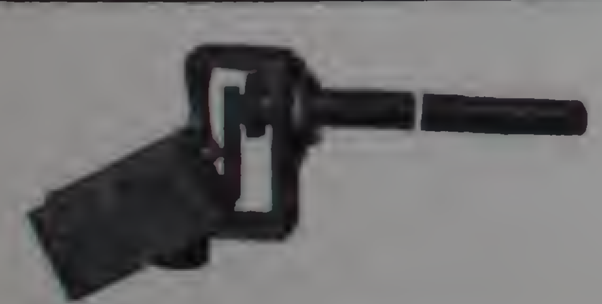
MOUNTING—Lugs on back of case.

ADJUSTMENT—Screws on top of case.

CONNECTION—¼" female pipe.

DIMENSIONS—Height 8¾", width, 9¼", depth, 3".

WHEN ORDERING SPECIFY:
1. Type number.
2. Difference in temperature to be maintained.
3. Maximum and minimum temperature to which control may be subjected.
4. Element lengths.
5. Application details.



AIRSTREAM THERMOSTATS

The Airstream Insertion Thermostat is an air-operated low limit controller for mounting directly in the discharge from a unit ventilator.

TYPES

L093A—Graduate, one-pipe, direct acting.

SPECIFICATIONS

THROTTLING RANGE—6° F., non-adjustable.
PRESSURE RANGE: 0 to 15 lbs.
OPERATING ELEMENT—Brass tube and 18" invar rod.
RANGE: 40° to 150° F.

ADJUSTMENT MEANS—Knurled knob.
DIMENSIONS—Height, 2¼"; width, ¾"; depth, 2⅛".
WHEN ORDERING SPECIFY:
1. Type number.
2. Mfr. of Unit Ventilator and type number.

See New Electronic Humidity Control – Bulletin SA1804-HCA

PNEUMATIC CONTROLS
HUMIDITY AND PRESSURE CONTROLS

ROOM HUMID-U-STATS★

Humid-U-Stats, pneumatic humidity controllers, are actuated by human hair elements, the most sensitive element known for this purpose. In addition, they are equipped with temperature compensators to insure accurate control regardless of temperature changes. The wide adjustable throttling range makes it possible to use this Humid-U-Stat as a master control.

TYPES

H0900A—Graduate one-pipe direct acting.
H0900B—Graduate one-pipe reverse acting.

SPECIFICATIONS

RANGE: 20 to 80% R.H.

THROTTLING RANGE—Adjustable 1 to 30%.

PRESSURE RANGE: 0 to 15 lbs.

SCALE MARKING: 20 , 50, 80.

MOUNTING—Flush mounting standard; surface mounting available.

ADJUSTMENT MEANS—Removable key standard; Special: external knob.

COVER—Locking type.

FINISH—Silver bronze standard; Special finishes available at extra cost.

OPERATING ELEMENT—Human hair.

★Trade Mark

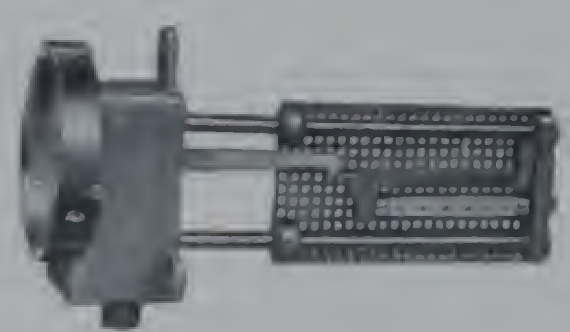
DIMENSIONS—Humid-U-Stat: Height, 3"; width, 4⅞"; depth, 1¾". Wall box: Height, 2¼"; width, 4½"; depth, 3".

FITTINGS—Flexible connectors in wall box or copper tubing in surface box. Copper tubing in wall box at extra cost.

WHEN ORDERING SPECIFY:

1. Type number.
2. Key or knob adjustment.
3. Finish.
4. Flush or surface mounting.
5. Fittings.

INSERTION TYPE HUMIDITY CONTROLLERS



Air-operated Insertion Type Humidity Controllers may be used where it is impossible to find a satisfactory location for a wall mounted type unit. These controls employ a Buckeye wooden strip as the humidity sensitive element.

TYPES

H094A—Graduate, direct, one-pipe.
H094B—Same as H094A except reverse acting.
H097A—Master direct acting, one-pipe.
H097B—Same as H097A except reverse acting.
H098A—Submaster, reverse acting. An increase in auxiliary bellows pressure raises control point 10% to 30%.

SPECIFICATIONS

RANGE AND DIFFERENTIAL—

TYPE	HUMIDITY RANGE	THROTTLING RANGE
H094	25–90%	3%
H097	25–90%	5–25%
H098	25–90%	4–36%

SCALE MARKINGS—5% intervals.

PRESSURE RANGE—0 to 15 lbs.

OPERATING ELEMENT—Buckeye wooden strip.

ELEMENT DIMENSIONS—Length, 6¼"; height, 2½"; width ¾".

ADJUSTMENT MEANS—Adjusting screw.

DIMENSIONS—Height, 4"; width, 3¼"; depth, 2".

WHEN ORDERING SPECIFY:

1. Type number.

STATIC PRESSURE REGULATOR

The Pneumatic Static Pressure Regulator is a gradual acting type controller for maintaining a constant static pressure in supply ducts, combustion chambers, etc. It may be used to control pneumatic motor units operating dampers, valves, etc.

TYPES

P0900A—Graduate, direct or reverse, one-pipe.

SPECIFICATIONS

RANGE AND DIFFERENTIAL—Range, 0 to 2" pressure and 0 to 2" vacuum; differential adjustable, .075 to .75" of water column. Special relay available for higher pressures.

PRESSURE RANGE—0 to 15 lbs.

ADJUSTMENT MEANS—Spring.

DIMENSIONS—Height, 7"; width, 12⅛"; depth, 5⅞".

WHEN ORDERING SPECIFY:

1. Type number.
2. Outdoor duct head assembly if required.

PNEUMATIC CONTROLS
MOTORS—PRESSURE CONTROLS

PRESSURE CONTROLLER

Pneumatic Pressure Controllers are pressure actuated pneumatic devices which vary the branch line air pressure as the pressure in the control bellows changes. These controllers can be used wherever it is necessary to control pneumatic equipment from pressure. Furnished complete with fittings.

TYPE

P097A—One-pipe, gradual acting, for either direct or reverse operation. Pressure in branch line increases from 0 to 15 lbs. with lever set at "direct" as pressure of medium under control increases.

SPECIFICATIONS

RANGE AND DIFFERENTIAL—

TEMPERATURE RANGE	THROTTLING RANGE
22 in. vac. — 35 lbs.	1 in. vac. — 3.5 lbs.
0 — 16 oz.	———
0 — 15 lbs.	.1 — 1.5 lbs.
2 — 50 lbs.	.4 — 4 lbs.
5 — 150 lbs.	.9 — 6.5 lbs.
10 — 300 lbs.	2.5 — 12 lbs.

ADJUSTMENT MEANS—Knurled knob.
TYPE OF MOUNTING—Mounting lugs on case.
DIMENSIONS—Height, 7"; width, 5"; depth, 3⅛".

WHEN ORDERING SPECIFY:
1. Type number.
2. Range.

DIFFERENTIAL PRESSURETROL

The differential pressure controller reacts to changes in the difference in pressure as measured at two points, rather than operating at a specific pressure setting. It finds wide application, therefore, as a differential pressure controller or as an alarm in detecting extremes in differential pressures.

TYPE

P0903A—Graduate one pipe, direct or reverse acting.

SPECIFICATIONS

RANGE OF DIFFERENCE IN PRESSURE TO BE MAINTAINED: 0 to 22 lbs.
THROTTLING RANGE: 8 ozs. to 26 ozs.
OPERATING ELEMENTS—Two opposed bellows.
SCALE—Blank—To be marked as desired.
MOUNTING—Lugs on back of case.
ADJUSTMENT—Screws on top of case.
CONNECTION—¼" female pipe.
DIMENSIONS—Height, 8¾"; width, 9¼"; depth, 3".
MAXIMUM BELLOWS PRESSURE—85 lbs. per square inch.

WHEN ORDERING SPECIFY:
1. Type number.
2. Difference in pressure to be maintained.
3. Complete application details.

DAMPER MOTORS

The Pneumatic Metaphram Motor may be used to position either valves or dampers in response to demands of an air-operated controller. These motors are operated by Metaphrams which are constructed of "Admirality" brass. Metaphrams are assembled in sections and may be individually replaced.

TYPES
M052A — 4" size—For Louvre or Mixing Dampers.
M052B — 5½" size—For Louvre or Mixing Dampers.
M052C — 7" size—For Louvre or Mixing Dampers.
M052D —10" size—For Louvre or Mixing Dampers.
M0513 —Gradutrol Unit Ventilator Motor.
M0514 —Non-Gradutrol Unit Ventilator Motor.

SPECIFICATIONS

PRESSURE RANGE—0-15 lbs.

DAMPER RATING—

METAPHRAM SIZE	GRADUATE ACTION	POSITIVE OR GRADUTROL ACTION
4"	2 sq. ft.	2½ sq. ft.
5½"	5 sq. ft.	6 sq. ft.
7"	12 sq. ft.	15 sq. ft.
10"	20 sq. ft.	24 sq. ft.

Note: When used in combination with the Gradutrol Relay the positive action ratings also apply for graduate action.

MOUNTING—Internal and external brackets and linkages for every type of service.
Adjustable spring device available for types M052C, and M052D.

WHEN ORDERING SPECIFY:
1. Type number.
2. Type of mounting.
3. Type of damper to be operated.
4. For Unit Ventilators, give mfgr. name, model number and application including cycle.

PNEUMATIC CONTROLS
PNEUMATIC VALVES — MOTORS

THE GRAD-U-MOTOR

The Grad-U-Motor is a neatly designed compactly built power unit for positioning dampers. The power unit consists of a composition bellows constructed especially to provide long service.

Adjustable stops limit the maximum and minimum travel of the motor.

TYPE
M0900A Grad-U-Motor—For positive positioning of dampers. (3" size).
M0900B Grad-U-Motor—For positive positioning of dampers. (3 13/16" size).
M0900C Grad-U-Motor—For positive positioning of dampers. (6" size).

SPECIFICATIONS

DAMPER RATING AND MOTOR STROKE

Type	Damper Rating in Sq. Ft.		Force of Stroke in Lbs.		Adjustable Stroke Length
	Graduate	Positive or Gradutrol	At either end	At center	
M0900A	4	5	8	23	2" Max.
M0900B	8	10	9½	28	2⅝" Max.
M0900C	40	48	42	112½	2" to 4" Max.

OPERATING RANGE—3 to 13 lbs.

AIR CONNECTION—⅛" iron pipe size.

MOUNTING MEANS—Universal bracket.

FINISH—Grey enamel.

WHEN ORDERING SPECIFY:

1. Type number.
2. (a) With or without bracket and linkage. (b) For normally open or normally closed type damper. (c) For mounting inside or outside duct.

Pneumatic Control Valves are available for application on heating and cooling coils in ventilating and air-conditioning systems. Metaphram power units are combined with globe type valve bodies to provide either gradual or positive action.

All valves may be obtained with the Gradutrol relay to provide positive positioning.

SPECIFICATIONS

TYPE O.	TOP SIZE	SEAT	VALVE SIZE	*ACTION
V053A	4"—Standard	Single	¼", ⅜", ½", ¾", 1", 1¼", 1½"	Direct
V053B	7"—Standard	Single	2", 2½", 3"	Direct
V053B	7"—Oversize	Single	½", ¾", 1", 1¼", 1½"	Direct
V053C	10"—Standard	Single	4", 5", 6"	Direct
V053C	10"—Oversize	Single	2", 2½", 3"	Direct
V053E	4"—Standard	Single	½", ¾", 1", 1¼"	Reverse
V053F	7"—Oversize	Single	½", ¾", 1", 1¼", 1½", 2"	Reverse
V054A	4"—Standard	Double	½", ¾", 1", 1¼", 1½", 2"	Direct
V054B	4"—Standard	Double	½", ¾", 1", 1¼", 1½", 2"	Reverse
V054C	7"—Standard	Double	2½", 3"	Direct
V054D	7"—Standard	Double	2½", 3"	Reverse
V054E	10"—Standard	Double	4", 5", 6", 8", 10", 12"	Direct
V054F	10"—Standard	Double	4", 5", 6", 8", 10", 12"	Reverse
V055A	4"—Standard	Three-Way	½", ¾", 1", 1¼", 1½", 2"	——
V055B	7"—Standard	Three-Way	2½", 3"	——
V055B	7"—Oversize	Three-Way	½", ¾", 1", 1¼", 1½", 2"	——
V055C	10"—Standard	Three-Way	4", 5", 6"	——
V055C	10"—Oversize	Three-Way	2½", 3"	——

GUIDES—V-port throttling guides on all V054, all V053 valves up to 3" inclusive, and V053 valves above 3" with 8# and 12# springs. Plain guides on V053 valves over 3" with 5# springs. Quick opening guides also available on V054 valves.

* Direct acting valves are normally open.
Reverse acting valves are normally closed.

Straight through body valves available for all types.

V053A, B, C—
Sizes ½" to 3"—screwed bronze body.
Sizes 2" to 3"—screwed iron body.
Sizes 4" to 6"—flanged iron body.

Flanged type also available in smaller sizes on special order.

Valve bodies 2" and smaller are of bronze; larger sizes are of iron. Bronze trim is standard. Stainless steel trim (and iron bodies in smaller sizes) are available at extra cost.

SPRING RANGE—Standard springs available so that valves close at 5, 8, or 12 lbs. air pressure.

MAXIMUM PRESSURE RATING—See Sec. 8, page 21.

WHEN ORDERING SPECIFY:

1. Type number.
2. Valve pattern.
3. Valve size.
4. Gradutrol relay if required (order separately).
5. Spring range.
6. Medium to be controlled.
7. Temperature and pressure of medium under control.

NOTE: Order companion flanges separately.

PNEUMATIC CONTROLS
PNEUMATIC VALVES

THE GRAD-U-TROL VALVES

The Grad-U-Trol Valve consists of a composition bellows power unit positioning the valve stem thru a linkage which provides characterized flow control.

The Grad-U-Trol Valve includes a built-in Grad-U-Trol Relay which provides for positive positioning of the valve and for sequence operation when required. It may be used as a normally open or normally closed valve by a simple change which can be made in the field.

An external indicator shows the position of the valve.

SPECIFICATIONS

TYPE	K0900A	K0901A
Sizes	½″ to 3″	½″ to 3″
Pattern	Single seated, screwed	Double seated, *screwed
Guides	Characterized V Port	Characterized V Port
Body Material	Bronze Body and trim all sizes	½″ to 2″ Bronze body and trim 2½″ to 3″ Iron body–bronze trim
Disc	Single Composition	Double bronze
Air Pressure	0-15#	0-15#

*Flanged type available on special order.

OPERATING RANGE — Adjustable 3 to 10 lbs. above starting point. Starting point adjustable 3 to 8 lbs.

MAXIMUM PRESSURE RATING—See Sec. 8, page 21.

WHEN ORDERING SPECIFY:
1. Type number.
2. Valve size.
3. Medium to be controlled.
4. Temperature and pressure of medium under control.

UNIT VENTILATOR VALVES

Unit Ventilator Valves of special construction provide full operation in response to a variation of a few pounds in branch line pressure.

TYPES
V056A—Direct acting or normally open.

SPECIFICATIONS

PIPE SIZES—¾″, 1″, 1¼″, 1½″, 2″.

VALVE PATTERN — Angle or straight through, single seated, screwed

SPRING RANGES—3 to 8 lbs., 6 to 11 lbs., 2 to 12 lbs., or 8 to 12 lbs.

AIR CONNECTION—⅛″ pipe tap.

CAPACITY—Use 80% of values shown for V053 in Sec. 8, page 21.

WHEN ORDERING SPECIFY:
1. Type number.
2. Size.
3. Steam pressure.
4. Valve pattern.
5. Spring range.

RADIATOR VALVES

Pneumatic Radiator Valves are available in sizes up to 2 inches. Metaphram power units are mounted integrally with globe type valve bodies. These valves may be used for gradual or positive action service, and are normally open, or direct-acting. Valves with 10 lb. springs are equipped with V-port skirts.

TYPES
V0500A—Valve made up of 4″ Metaphrams.
V052B—Valve made up of 3″ metaphrams available only for ½″, ¾″, and 1″.

SPECIFICATIONS

FINISH—Silver Bronze.

PIPE SIZES—½″, ¾″, 1″, 1¼″, 1½″, 2″.

VALVE PATTERN—Angle or straight through.

SPRING RANGE—3 to 10 lbs. for graduate action of direct radiation. 1 to 4 lbs. for positive action of direct radiation with unit ventilators.

WHEN ORDERING SPECIFY:
1. Type number. 2. Size. 3. Steam pressure.
4. Valve pattern. 5. Spring range.

VALVE SIZE	PRESSURE RATINGS	
	4# Valve Spring	10# Valve Spring
V052B, Single Seated, 3″ Tops		
½″ Screwed	50	48
¾″ Screwed	36	18
1″ Screwed	18	9

PNEUMATIC CONTROLS
ACCESSORIES


L404H


R047


R048


R049

RELAYS

Various types of Pneumatic Relays are necessary to transfer the effect of a controller, to switch from a pneumatic to an electric impulse, to switch from an electric to a pneumatic impulse, etc. Pneumatic Relays provide all these functions.


R095A

TYPES

L404H—Pneumatic Electric Relay. SPDT Switch operates on pressure change of 1½ lbs. min. to 12½ lbs. max. Electric Rating 10 Amps., 115/60; 5 Amps., 230/60; 1 H.P. A.C.

R047A—Special Electric Pneumatic Relay for use with unit ventilators.

R048A—Diverting Relay. May be used as stop and waste relay to stop supply line and bleed branch line on either an increase or decrease in pressure on diaphragm, or as a diverting relay to divert the flow of air from one line to either of two other lines on a rise or fall in pressure on the diaphragm.

R048B—Diverting Relay. Used with two graduate controllers so that the controller with the highest or lowest branch pressure will be given control of the controlled device.


R097A

R049A—Positive Pneumatic Relay. Admits air to branch line on an increase in pressure, releases air on a decrease. Adjustable to operate at any pressure between 4 and 17 lbs. Differential 2 lbs. non-adjustable. May also be used as a diverting relay.

R094A—Gradutrol Relay. For application to damper motors. Provides for infinite and accurate positioning of dampers. Maximum power of motor is immediately available to produce true graduate action of damper.

R094B—Gradutrol Relay. Same as R094A except for application to control valves.

R095A—Grad-U-Relay, direct acting. Maintains pressure in secondary line equal to that in thermostat branch line.

R095B—Grad-U-Relay, reverse acting. Reduces pressure in secondary line proportionately as pressure increases in thermostat branch line.


R0400A

R095C—Branch line pressure to controlled device is average of branch line pressure from two controllers.

R095D—Pressure relief valve to bleed main down to 13½# when main pressure is switched to 13# from 17#.

R097A—Pneumatic Electric Relay. Snap acting single pole double throw relay, designed to convert gradual air pressure changes into positive electric switching action. May be used to control an electrical device such as heater, motor, signal lights, etc., in conjunction with a pneumatic temperature controller.

R0400A-Electric Pneumatic Relay. Electrically operated pneumatic diverting relay, used where an inter-lock is desired between the electrical system, such as a fan, and the pneumatic control system. Can be used as a stop-and-bleed valve or as a diverting valve, diverting air from a common line to either of two branches.


S047 (mounted)

WHEN ORDERING SPECIFY: 1. Type number. 2. Application. 3. Voltage and frequency.

PNEUMATIC CONTROLS

ACCESSORIES

MANUAL SWITCHES

TYPES

S047A—Diverting switch. ⅛, ⅜ and ½″ sizes. Two-position. Used to feed air to a branch line in one position, and stop the main and bleed the branch in the other position.

S047B—Diverting switch. ⅛, ⅜ and ½″ sizes. Two-position. Used to divert one air line to either of two lines.

S047C—Diverting switch. ⅛″, ⅜″ and ½″ sizes. Two-position. Used with T096 Summer-Winter Thermostat or to divert a line to either of two other lines and bleed the line not in use.

S047D—Diverting switch. ⅛″, ⅜″ and ½″ sizes. Three-position. Used as an "Open-Closed Automatic" switch or for any similar purpose.

S048A—Diverting switch. ⅛″ size. Two-position. Used for connecting two air lines in one position and for connecting two separate lines in the other position, or for any similar purpose.

S048B—Diverting switch. ⅛″ size. Used to connect one air line to four others in a predetermined sequence.

S049A—Push button switch, two-position. Holds pneumatic valves or motors in open or closed position.

S092A—Grad-U-Switch. For varying the air pressure in a branch line from 0 to 15 lbs. manually from a remote point.

S092B—Grad-U-Switch. A remote means for manually setting valves or dampers in any position from wide open to tight closed.

WHEN ORDERING SPECIFY:

1. Type number.
2. Application.
3. Type of panel: steel (standard), slate or Ebonite.
4. Card designation.

AIR COMPRESSORS

A reliable supply of air at 15 lbs. pressure is required for every pneumatic installation. Compressor equipment is supplied complete with tank, pressure regulator, pressure switch, filter, etc.

TYPE	H. P.	DELIVERY	CAPACITY (Room Stats)			VOLTAGE	TANK
			*	▲	ƒ		
W010A	¼	.93 cu. ft.	10	10	10	115/60 or 230/60 Single Phase	4 Gal. Self-Contained
W010A	¼	.93 " "	12	24	40	115/60 or 230/60 Single Phase	30 Gal. Self-Contained
W010B	⅓	1.64 " "	28	56	70	115/60 or 230/60 Single Phase	30 Gal. Self-Contained
W010C	½	2.54 " "	70	140	110	230/60 Three Phase	30 Gal. Self-Contained
W010D	¾	3.71 " "	110	220	160	230/60 Three Phase	30 Gal. Separate
W010E	1	4.76 " "	140	280	200	230/60 Three Phase	52 Gal. Separate
W010F	1½	10.2 " "	350	700	450	230/60 Three Phase	Two 52 Gal. Separate

*With bleed type thermostats (50% compressor operation).
▲With bleed type thermostats and Gradutrol Relays (50% operation).
ƒWith non-bleed type thermostats (33⅓%) operation).

WHEN ORDERING SPECIFY:

1. Type number.
2. Motor voltage, phase and frequency.
3. With or without tank.

MOISTURE CONDENSERS

Moisture Condensers remove the moisture from the compressed air which is to be used by pneumatic controls. These condensers are normally required only when the control equipment is used with a cooling system.

TYPES

W015A—Air cooled.
W016A—Water cooled.

SPECIFICATIONS

Furnished with either a water trap to drain the condensate to the sewer or a condensate receiver which must be emptied periodically.

CAPACITY—20 C.F.M.

WHEN ORDERING SPECIFY:

1. Type number.
2. Cooling medium.
3. Air capacity.
4. With trap or receiver.

PNEUMATIC CONTROLS

ACCESSORIES

HUMIDIFIERS

The Humidifier increases the moisture content of the air and is for use with pneumatic controls in the conditioning of auditoriums, schools, theatres, etc.

TYPES

W020A—Pan type with self-contained float.
W020B—Pan type with separate float box.
W021A—Injector type.

SPECIFICATIONS

1. The pan type humidifier consists of a steam coil immersed in a pan of water. The coils are 1½″ iron pipe of sufficient length to provide the required evaporation of moisture and the pan is constructed of heavy metal.
2. The pan type humidifier may be used where the steam pressure is as low as 5 lbs. per square inch although 25 lbs. or more is recommended.
3. The injector type humidifier should be installed where the steam pressure is not more than 5 lbs. per square inch. 2″ pipe with ½″ holes on 2″ centers.

WHEN ORDERING SPECIFY:

1. Type number.
2. Steam pressure.
3. Air capacity.
4. Space limitations.
5. Relative humidity and temperature of entering and leaving air.

ORDERING INFORMATION

TYPES W020A AND W020B—PAN TYPE

Refer to Table I for length of pipe necessary. This is determined by the C.F.M. of air to be humidified, and the steam pressure available. In order to complete the O.S. number, determine the length of pipe necessary, and use this figure (in feet) after the type number.

For example, a job handling 20,000 C.F.M. of air and a 50 pound steam pressure requires 13 feet of pipe (see Table I). The O.S. number for a pan humidifier without a separate float box would then become W020A13. If a separate float box is required, the O.S. number would be W020B13.

The valve size required is also listed in Table I. For the above example, a reverse acting (normally closed) valve of 1″ size is necessary.

Always indicate the size valve to be used on the humidifier order.

Always specify space available in unit for humidifier

Always specify steam pressure and C.F.M. of unit

TYPE W021A—INJECTOR TYPE

To determine length of pipe necessary, determine the inside width of the unit at the humidifier location. Deduct approximately 12″ from this dimension to obtain the length of pipe necessary. Use this figure to complete the O.S. number.

Referring to the example under W020A if the unit is 7 feet wide at the point where an injector humidifier is to be installed, subtracting 12 inches from this figure leaves 6 feet. The O.S. number for an injector humidifier for this job would be W021A6.

The valve size is obtained from Table I, and is determined by the C.F.M. passed through the unit. Hence, for this job a 1″ valve is necessary.

Always indicate the valve size necessary when ordering the humidifier.

NOTE: The length of the injector should be not less than 3 feet nor more than 10 feet.

LINEAL FEET OF 1½″ PIPE REQUIRED FOR PAN HUMIDIFIERS

Cu. Ft. of Air Per Minute	*Valve Size	Steam Pressure in Pounds						
		5	10	15	20	25	50	100
5,000	½″	18	10	8	6	5	4	3
10,000	¾″	36	20	15	12	10	7	5
20,000	1″	72	40	30	24	20	13	9
30,000	1¼″	108	60	45	36	30	20	13
40,000	1½″	144	80	60	48	40	27	18
50,000	2″		100	75	60	50	33	22
75,000	2½″		150	110	92	75	50	33
100,000	3″			150	120	100	65	44

*Valve sizes also apply to injector type humidifier. For injector type requiring 2½″ valve use two injectors. Injectors to be connected on a heater.

Table I.

The above table is based upon an entering air condition of 35° dry bulb with 40% relative humidity and a final condition of 70° dry bulb with 40% relative humidity.

To determine the length of pipe necessary for some other set of conditions, refer to a Psychrometric Chart and determine the grains of moisture to be added per pound of dry air.

Having this figure proceed as follows:

1. Determine length of pipe as shown in the example, (see page 1), using Table I above.
2. Multiply this figure by the grains of moisture added per pound of dry air as determined from the Psychrometric Chart.
3. Divide the result of (2) above by 33. This gives the corrected figure for feet of pipe necessary .

For example, suppose that in the illustration, the specifications called for a final condition of 70° dry bulb and 50% relative humidity with an entering condition of 35° dry bulb and 40% relative humidity.

Referring to a Pyschrometric Chart we find the grains of moisture per pound of dry air as following — for the final condition, 55 grains, and for the entering condition, 11.5 grains. The difference is then 43.5 grains.

We have found from Table I that 13 feet of pipe is normally required. Multiplying 13 by 43.5, we get 565.5. Dividing this figure by 33, we get 17.13. For this job we would then order a W020A17 or W020B17 humidifier.

DAMPERS

DAMPERS

Control dampers play an important part in nearly all heating, ventilating and air-conditioning systems. In order to provide proper control, these dampers must be constructed with certain characteristics which vary to meet the requirements of a particular installation.

Minneapolis-Honeywell control dampers have been especially designed for temperature control work and are available in every type and variety. Dampers can be positioned with either pneumatic or electric damper motors.

TYPES

W42—Louvre dampers.
W43—Right angle mixing dampers.
W44—Round dampers.

Type W42 Louvre damper with electric motor operator mounted externally to duct.

Type W42 Louvre damper with Pneumatic motor operator mounted directly on damper. See page 38 for M0900 Damper Motor.

SPECIFICATIONS

FRAMES—For dampers under 10 sq. ft. area, welded 2"x½"x⅛" black channel iron except mixing type damper frame of 3/16"x2" strap iron if no dimension exceeds 18". For dampers over 10 sq. ft. area welded 2"x1"x⅛" channel.

BLADES—No. 16 gauge steel. Maximum width 10" except round dampers 36" dia. Maximum length 48". Blades have one center and two edge crimps. Where required, the driving blade is reinforced.

FINISH—Black enamel finish standard.

BRACES — Dampers over 16" in any dimension have corner braces. Dampers over 30" in height have tie rods 24" or less apart. Additional braces on frames or blades wherever required.

BEARINGS—Steel shaft in brass bearings.

GENERAL—Maximum height, 8 feet. Maximum area, 25 sq. ft. All dampers equipped with side and end stops of ¼"x⅝"x1/32" angles. All dampers over 8' height, 48" width, or 25 sq. ft. area are built in two or more sections with interconnections on every other blade. 5/16" holes drilled every 18" or less on all sides of damper frame for mounting. Special finish, special material, felted edges, etc., are available. Cross connections between blades are adjustable. All dampers are given double inspection for size, etc.

MOTOR AND MOTOR FITTINGS — PNEUMATIC — M052 Type—When pneumatic motors of the M052 type and their fittings for internal mounting are ordered with the damper, the lever is factory cut to fit, and is included with the damper. The motor mounting bracket is included with the fittings and mounting lugs for the brackets are provided on the damper frame.

Assorted sizes of leg stands and L brackets are available for external mounting of these motors on floor, wall, ceiling or duct work. The lever is included in the motor fittings for this case, but the mounting bracket must be ordered separately.

M0900 Type—The lever is a part of the motor, and the mounting bracket is included with the fittings. Mounting lugs are provided on the damper frame for the mounting bracket if this type of motor is to be mounted internally.

ELECTRIC—Internal Mounting—Motor mounting bracket and blade drive ear are included with damper for mounting M204, M405, M805, M904, and M905 Motors. Order Q605B linkage separately (from Minneapolis).

External Mounting—Extended axle provided for connecting linkage. Order Q605A linkage separately (from Minneapolis).

MOUNTING BRACKETS AND LINKAGES, Electric — Q605B, for mounting M204, M405, M805, M904 and M905 motors internally (inside duct). Q605A, for mounting M204, M405, M805, M904 and M905 motors externally (outside the duct).

SPECIAL FEATURES AVAILABLE—

(1) Copper dampers to be built to specifications of 20, 24, 32 or 36 ounce copper. Frames to be copper sprayed iron channel or brass bar stock.
(2) Gray enamel, copper spray, or aluminum finish.
(3) Galvanized blades with aluminum painted iron frames.
(4) Motor bracket mounting of internal or external type.
(5) Ball bearings.
(6) Felted edges.
(7) Opposed action blades.

WHEN ORDERING SPECIFY:

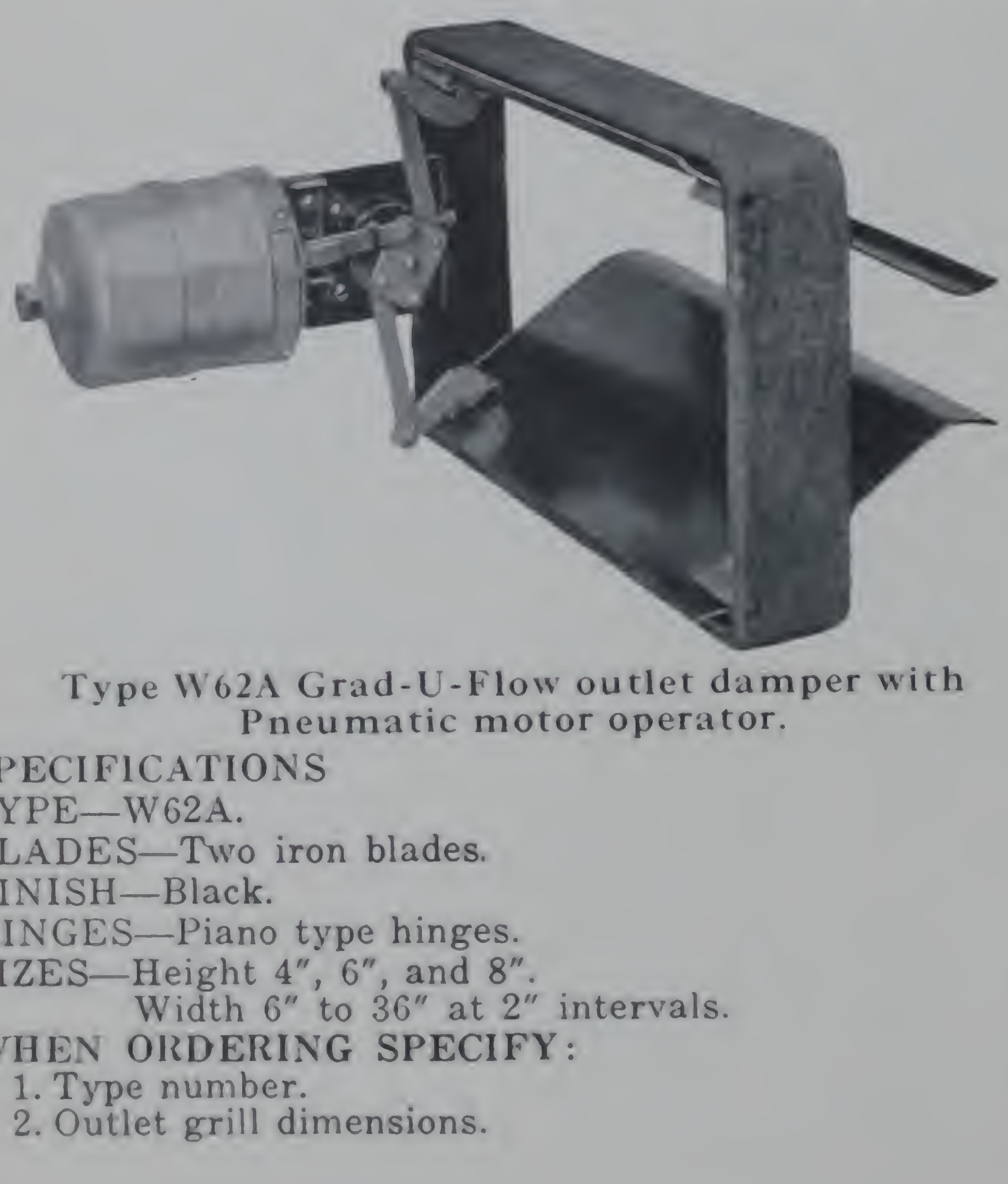
1. Type number.
2. Actual damper size. Do not give duct size, since dampers are built to exact size given.
3. Give complete specifications, using damper order form (SA-765).

DAMPERS

Type W44 Round damper with Pneumatic motor operator.

Type W43 Right angle mixing damper with Pneumatic motor operator.

GRAD-U-FLOW OUTLET DAMPER



Type W62A Grad-U-Flow outlet damper with Pneumatic motor operator.

SPECIFICATIONS
TYPE—W62A.
BLADES—Two iron blades.
FINISH—Black.
HINGES—Piano type hinges.
SIZES—Height 4", 6", and 8".
Width 6" to 36" at 2" intervals.
WHEN ORDERING SPECIFY:
1. Type number.
2. Outlet grill dimensions.

Grad-U-Flow outlet dampers, sold exclusively by Minneapolis-Honeywell, are designed primarily for use as volume dampers on zone systems using varying volume control. The Grad-U-Flow outlet damper varies the volume of air introduced to the outlet grill, while maintaining the velocity of the air stream at a constant value. Only the size of the air stream is varied according to the demands of the space.

Through the use of these constant velocity dampers, the air distribution remains the same for any outlet regardless of the quantity of air passing through the grill. Air passage through Grad-U-Flow outlet dampers is streamline and therefore eliminates turbulence and noise.

For best results, the system should include equipment to control the static pressure in the supply ducts.

Grad-U-Flow outlet dampers are available in standard grill sizes, listed under specifications.

BROWN INSTRUMENTS

for

INDICATING, RECORDING

and

CONTROLLING

SECTION II

Printed in U. S. A.

Brown Instruments

For Indicating, Recording and Controlling

In buildings where occupants' satisfaction means increased revenue for the owner, the control of temperature and humidity conditions within comfortable limits is the first essential. But of almost equal importance to the owner is an accurate check on the performance of the system, both from the standpoint of conditions maintained and the cost of operation.

Instruments, which are designed to provide accurate records of all variables which go to make up a complete air-conditioning system, will provide the owner with the information necessary to economically operate the system under optimum comfort conditions. For instance, Flow Meters in the line to the steam coils show steam consumption, the major cost factor during the heating cycle.

Temperature indicating and recording instruments will show wet and dry bulb conditions throughout the system itself and the space being conditioned, and in addition make possible readjustments that will permit more economical operation under conditions that have been determined to be satisfactory to occupants. Permanent records of this nature are invaluable in presenting to tenants a visual picture of the actual conditions that have been maintained.

Resistance Thermometer

Standardizing Panel

INDICATING RESISTANCE THERMOMETERS

The indicating resistance thermometer provides a means for measuring temperatures at remote points from a central location. The indicator is the direct-reading, deflectional type. The bulbs, or temperature sensitive elements, may be located at any distance up to 1,000 ft. from the instrument, and are easily connected by three small-gauge wires. The circuit used makes it possible to change bulb locations at will without recalibration or the addition of auxiliary resistances.

Types Available

9001-120A—Indicator complete with 18181 control panel for use with single bulb or rotary switches.

9001-120B—Indicator complete with 18182 control panel for use with multiple key switch assemblies.

Specifications

1. Range:—20° to +120° F., standard. Other ranges available on order.
2. Switching Mechanism: Self contained 24 point rotary switch.
3. Bulbs: Room or insertion type for either wet or dry bulb measurement.
4. Operating Current: Direct current dry cell battery.
5. Wiring: Two No. 18 B & S copper wire leads for each bulb and 1 No. 16 B & S copper wire common to all bulbs.

RECORDING RESISTANCE THERMOMETERS

Continuous strip chart recorders for obtaining permanent records of remote temperatures. Available to provide as many as six records. Record lines printed in contrasting colors to prevent confusion. Operates on potentiometer circuit.

Types Available

113X1W —1 record
113X5W2—2 records
113X5W3—3 records
113X5W4—4 records
113X5W6—6 records

Specifications

1. Range: —20° to +300° F., (minimum span 20° F., maximum 300° F.)
2. Bulbs: Room or insertion type for either wet or dry bulb measurement.
3. Operating Current: Chart motor 110/60 or 220/60—Bulb current dry cell battery.
4. Wiring: Two No. 18 B & S copper leads to each bulb. One No. 16 B & S copper lead common to all bulbs.
5. Also available with print wheel up to 16 records.

BROWN INSTRUMENTS

PRESSURE TYPE THERMOMETERS

Circular chart type recorders are available complete with connecting tubing and bulb for measuring wet and dry bulb temperatures or relative humidity. Available for either portable service or permanent mounting. Chart motor electric or spring wound type.

Types Available

645101—Single record thermometer 10″ chart. Rectangular case.
645121—Single record thermometer 12″ chart. Rectangular case.
6081-X01—Portable thermometer 8″ chart. Circular case.
645102-40—Two record thermometer 10″ chart. Rectangular case.
645122-40—Two record thermometer 12″ chart. Rectangular case.
645123-44—Three record thermometer 12″ chart. Rectangular case.
6081-X019—Portable recording thermometer 8″ chart. Circular case.
For Portable Combination Hair Hygrometer and Thermometer see following page.

Specifications

1. Ranges: Class II —10° to +600° F.
   Class III—40° to +800° F.
   Class IV—40° to +1000° F.
2. Tubing lengths: Five feet standard. Maximum lengths available.
   Class II —200 Ft.
   Class III—200 Ft.
   Class IV— 50 Ft. (Circular case)
   200 Ft. (Rectangular case)
3. Recording Pen: Reservoir type. Non-corrodible and replaceable.
4. Case Construction: Dust proof and moisture proof. Lock and key type cover.
5. Case Dimensions: 10 or 14 in. diameter (Circular case). 13 13/16x17 27/32″ (Rectangular case).

MECHANICAL FLOW METERS

Mechanical flow meters provide a means of measuring and recording both rate and total flow of any fluid. Such records make it possible to more accurately determine operating costs and system efficiency. Brown flow meters operate on the differential pressure principle. Mechanical meters are used where it is possible to locate the entire assembly close to the point of measurement.

Types Available

220121—Single pen recorder. Non-integrating type. 12″ chart.
221201—Single pen recorder with integrator and automatic planimeter. Total flow may be read directly. 12″ chart.
Multiple pen types are available to record temperatures or pressures simultaneously with flow.

Specifications

Range: Interchangeable range tubes provide easy readjustment of range for working pressures up to 2,500 lbs.
Integrator: Self contained in recorder case.
Meter Body: Standard forged steel meter body for universal application on all pressures up to 2,500 lbs.
Operating Mechanism: Simple lever and link connection between float and pen arm.

ELECTRIC FLOW METERS

Electric flow meters are used in place of mechanical assemblies where it is desirable to locate the recorder at a point remote from the point of measurement. A three wire electric circuit is employed to connect the meter body and recorder unit. Self contained integrators available for direct reading of total flow.

Types Available

200121—Single pen electric recorder with 12″ chart non-integrating type.

201201-X40—Single pen electric recorder with 12″ chart. Integrator built in recorder case for direct reading of total flow.

Specifications

Range: Interchangeable range tubes permit adjustment for all working pressures up to 2,500 lbs.
Meter Body: Universal forged steel body with divided inductance coil and armature assembly.
Wiring Connections: Terminal connections for 3 No. 16 wires are provided on both meter body and recorder units.

BROWN INSTRUMENTS

RECORDING HYGROMETERS

Hair Hygrometers give direct readings of per cent relative humidity. The pen is actuated by a sensitive bundle of human hairs through a simple lever system. The expansion and contraction of the hairs with changes in relative humidity is converted into pen motion over a uniformly graduated chart (reading 0 to 100%). The instrument gives quick and accurate response to changing air conditions wherever it is located.

Types Available

6881—Surface mounting, electric chart motor, 8″ chart
6881-X019—Portable, spring chart motor, 8″ chart.

Specifications

1. Range: 0—100% Relative Humidity.
2. Recording Pen: Reservoir type. Non-corrodible and replaceable.
3. Case: Circular dustproof die cast aluminum. Lock cover.
4. Dimensions: 10 inches diameter.

COMBINATION PORTABLE RECORDING THERMOMETER AND HYGROMETER

Combination Portable Recording Thermometers and Hygrometers make ideal instruments for spot checking the temperature and humidity conditions being maintained in a space for an entire 24 hour period.

They are made up in neat die cast cases with carrying handles and sturdy feet so that they can be set on any flat surface. A hand wound 24 hour clock movement makes them entirely self contained.

Types Available

6882-6019—Two pen recorder 8″ chart.

Specifications

1. Range: Temperature 0 to 100°.
   Relative Humidity 0 to 100%.
2. Recording Pen: Reservoir type. Non-corroding and replaceable.
3. Case: Circular dustproof die cast aluminum. Lock cover.
4. Dimensions: 10 inches diameter.

RECORDING PRESSURE GAUGES

Recording Pressure Gauges are available in a wide variety of ranges to provide a means for obtaining continuous records of boiler pressures, water pressure, or any other important pressure or vacuum. These units are available in the attractive new rectangular case design.

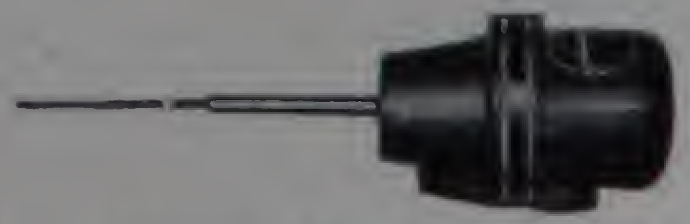
Types Available

705101—Single pen electric recorder with 12″ chart.
705122—Two pen electric recorder with 12″ chart.
705123—Three pen electric recorder with 12″ chart.

Specifications

1. Range: 0 to 30″ Hg. vac.
   0 to 6, 0 to 14, 14.7 to 600, 601 to 1000, 1001 to 7500 lbs.
2. Recording Pen: Reservoir type. Non-corroding and replaceable.
3. Case: Rectangular dustproof with locking cover.
4. Dimensions: 13 13/16 x 17 27/32 inches.

BROWN INSTRUMENTS



Flame Electrode

Photo Electrode Relay

Protectoglo Flame Relay

COMBUSTION SAFEGUARD SYSTEMS

Combustion safeguard systems are applied to large gas or oil fired installations to guard against hazardous conditions. Many variations in sequence and equipment are available and the choice of system will depend upon the type, size, and use of the burner involved.

For gas installations the Flame Electrode Protectoglo System is recommended. Systems can be arranged which check the presence of only the pilot flame, or which will check both the pilot and the main flame. If desirable, systems can be specified which will regulate the entire sequence of the burner in order to guard against any hazardous condition.

The Photo-Electrode Protectoglo System is available for oil fired boilers and other luminous type flames. The system uses the photo-electrode principle to detect the presence of flame and can be worked into many different combustion safe guard systems.

PYROMETERS

ELECTRONIK POTENTIOMETER PYROMETER—Strip Chart (153X60 Series).

A dependable instrument which can be located any distance from the point of temperature measurement without affecting its accuracy (within $\pm$ .02 MV for spans less than 10 millivolts). Pen speed allows full scale pen travel in 24 seconds.

Balancing motor and mechanism move only during a pointer change, reducing wear of parts to an absolute minimum. Accessories available to meet the needs of each job.

Charts are 12″ wide and 120′ long, with calibrated width of 11″ and standard time marking of 2″ per hour.

ELECTRONIK POTENTIOMETER PYROMETER—Circular Chart.

Recommended for use where ruggedness is desired with accuracy within .03 mv. for spans less than 12 mv. The entire balancing operation is non-cyclic and responds instantly to a change in measured e.m.f.

Full scale pen travel in 24 seconds (60 cycle) records continuous ink record on 12″ diam. charts with calibrated width of 4⅝″. Accessories available for all requirements.

Indicating and Recording Equipment

In buildings where occupants' satisfaction means increased revenue for the owner, the control of temperature and humidity conditions within comfortable limits is the first essential. But of almost equal importance to the owner is an accurate check on the performance of the system, both from the standpoint of conditions maintained and the cost of operation.

Instruments, which are designed to provide accurate records of all variables which go to make up a complete air-conditioning system, will provide the owner with the information necessary to economically operate the system under optimum comfort conditions. For instance, Flow Meters in the line to the steam coils show steam consumption, the major cost factor during the heating cycle; and an electric CO_2 meter analyzing the flue gas from the boiler permits an intelligent adjustment of the firing means so that the steam consumed may be produced at the lowest cost per unit of fuel input.

Temperature indicating and recording instruments will show wet and dry bulb conditions throughout the system itself and the space being conditioned, and in addition make possible readjustments that will permit more economical operation under conditions that have been determined to be satisfactory to occupants. Permanent records of this nature are invaluable in presenting to tenants a visual picture of the actual conditions that have been maintained.

Architects and engineers specifying instruments to be used with air-conditioning or space heating installations demand:

1. **Ease of installation.**
2. **Service facilities, whenever and wherever needed.**
3. **Dependable, accurate results.**
4. **One responsibility for the complete installation, backed by a financially sound company whose reputation is based on years of successfully applied instrumentation.**

The Brown Instrument Division of the Minneapolis-Honeywell Regulator Company, through its nation-wide sales and service organization, capably fills these requirements.

RESISTANCE THERMOMETERS

The flexibility of Brown Resistance Thermometers permits the measurement of temperatures electrically throughout the air-conditioning system and the space to be conditioned. The bulbs, or temperature-sensitive elements, of the instruments are located in suitable positions to measure the following conditions:

1. **Wet and dry bulb temperature in outside air.**
2. **Wet and dry bulb temperature in return air.**
3. **Wet and dry bulb temperature in discharge air.**
4. **Dewpoint temperature in dehumidifier outlets.**
5. **Temperatures at the inlets and outlets of cooling or heating coils.**
6. **Room temperatures.**

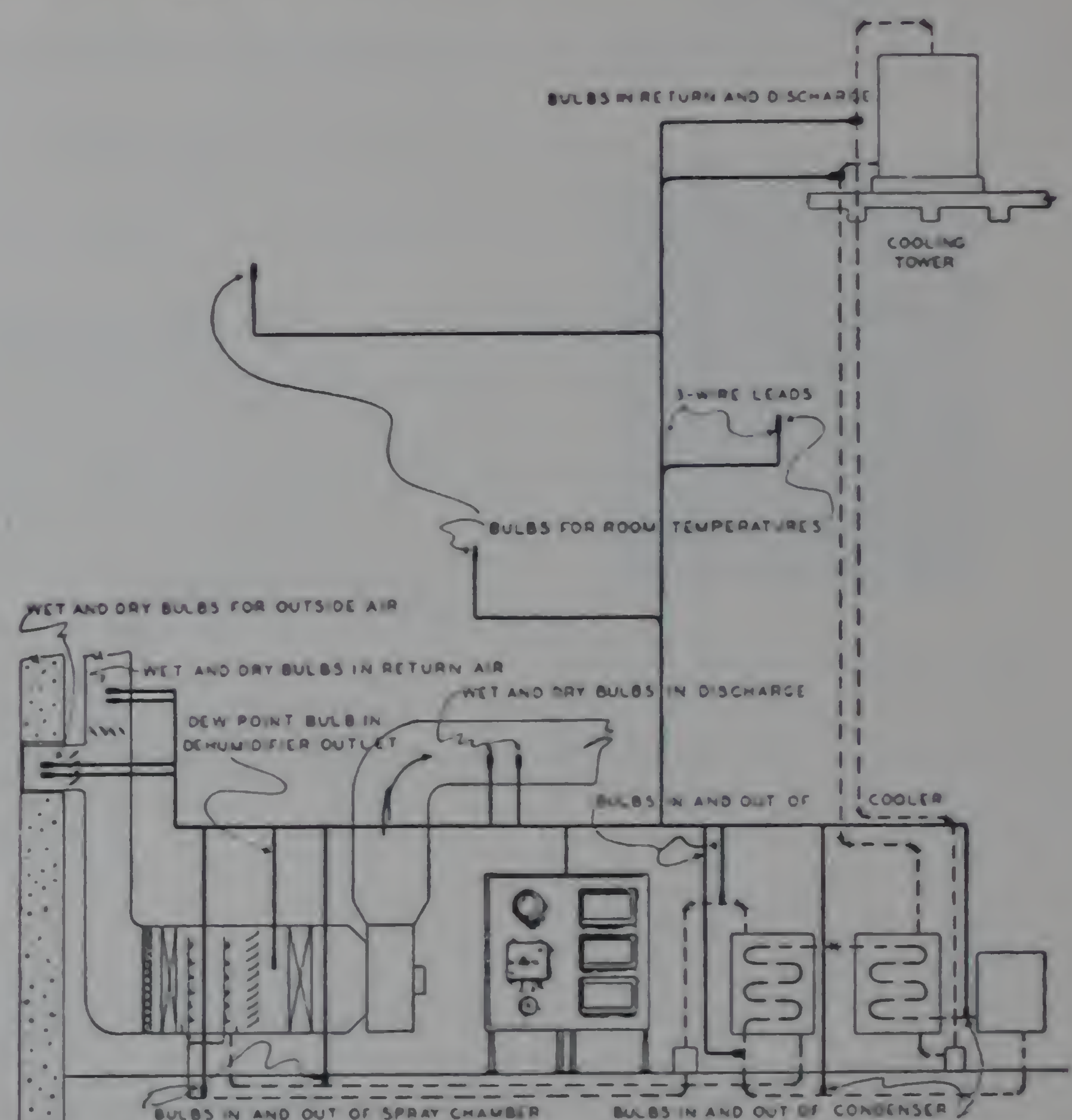
Resistance Thermometer Advantages

1. Wide range. Instruments are available to measure temperatures from 150° F. below zero to as high as 300° F. above zero.
2. Measures temperatures at any number of points.
3. Measures temperatures at practically any distance from the instrument.
4. Bulbs are small, sensitive, accurate, and interchangeable.
5. Instruments are available in any desired range.
6. Charts are uniformly graduated over the entire scale range.
7. No gas, mercury or liquid to leak.
8. Temperatures or humidities may be indicated or recorded as desired.
9. Attractive appearance.
10. Operation is based on the Wheatstone Bridge circuit which is the most accurate known.

Direct-Reading Indicating Resistance Thermometers (Deflection Type)

To meet the demands of building owners and operators for a centrally located instrument which will accurately indicate the temperatures throughout the building, the Model 9001, resistance thermometer was developed. All of the important temperatures throughout the office building, apartment, hotel or school can be quickly and accurately checked by the engineer from a central location. Simply by pressing a switch and turning a knob, remote temperatures are clearly indicated on a large open dial.

Since many building operators require that the installation of such equipment be made by their own electricians, a simple, easily installed circuit was developed for use with this type of instrument.



SCHEMATIC LAYOUT OF BULBS AND INSTRUMENTS OF A 3-WIRE RESISTANCE THERMOMETER SYSTEM AS USED IN A TYPICAL AIR-CONDITIONING INSTALLATION.

Figure 1

In the typical installation shown in Fig. 1 above, one No. 16 gauge wire and two No. 18 gauge wires are run to each bulb, and the system is so arranged that the 16-gauge wire may be common to all bulbs. Through this arrangement bulbs may be economically installed as far away from the instrument panel as 1,000 feet without increasing the wire size.

Indicating Resistance Thermometers (Balanced Bridge Type)

With the balanced bridge type of Resistance Thermometer the temperature reading is obtained by turning a dial to balance the Wheatstone Bridge Circuit. The temperature of the thermometer bulb is then read directly from the scale of the dial. A long 16" scale enables the observer to read small temperature changes with a high degree of precision.

INDICATING AND RECORDING EQUIPMENT

As in the case of the deflectional type instrument, a Brown balanced bridge indicator requires no calibration adjustment in the field to compensate for varying lead lengths. It may be used in combination with a large number of bulbs located at distant points when a suitable switching means is provided.

Single or Multiple Record Resistance Thermometers

Where a permanent record of operation is desired to show temperatures, load conditions, dehumidifier operations, cooling system and heating system operation, a Recorder is commonly used. Since the temperatures recorded become a permanent record, they serve as an invaluable reference for the building owner in checking operating efficiency and in serving to satisfy tenants as to the actual conditions under which the system is being maintained.

The Brown Recording Resistance Thermometer is available in either the single pen type, which makes a continuous line on the chart, or the multiple recording type which prints up to six different records of important temperatures in distinctive colors, and if desired, each record may be continuously numbered.

Assemblies for Wet and Dry Bulb Temperature Measurements

Brown Resistance Thermometers are excellently adapted to accurately measure and record both wet and dry bulb temperatures. By the use of two bulbs, one of which is covered by a wick extending into a tank of water, the wet bulb temperature can easily be determined by switching the connected instrument from one bulb to the other, or both readings may be obtained simultaneously. A suitable table supplied by us enables the user to read the percentage of humidity, dependent on the difference in temperature of the two bulbs. Certain types of recorders are calibrated so that relative humidity may be read directly.

Pressure Type Thermometers

In many cases where relatively few temperatures are to be recorded and where the instrument itself may be placed quite close to the point at which the temperature is being measured, the pressure type thermometer may be used advantageously. These recorders may be actuated by vapor pressure, gas expansion, or mercury expansion and are available to meet the requirements of varying applications. Pressure type thermometers are available for permanent installations, or may be of the portable type.

Building Engineers find frequent use for a portable two-pen temperature and humidity recorder. Many times in the checking and balancing of air-conditioning systems it is necessary for the architect or operating engineer to record temperatures at various points throughout the system which are not ordinarily served by other temperature recording means. The portable instrument gives a continuous record over a 24-hour period, and shows temperature and humidity at the point where the instrument is located.

Brown Recording Pressure and Vacuum Gauges

Many applications are found for a Brown two-pen Recording Pressure Gauge. During the heating cycle the advantages of maintaining a record of the boiler pressure or vacuum is obvious. During the cooling cycle it may be of prime importance to the operator to have a continuous record of the operation of a refrigeration compressor as shown by the pressures in the suction and discharge line. Other operating factors susceptible to interpretation through readings of pressure or vacuum will become of more or less importance in different systems depending upon the construction of the system itself. For instance, it may be desired to record the inlet and the outlet pressures to and from a cooling coil; or it may be desired to record the head pressures under which a pump must operate in cooling tower applications.

A variety of models is available with either circular twenty-four hour charts or with strip charts which furnish a record of approximately two months' operation.

CONTROL OF STEAM GENERATION

The savings possible through proper control of steam distribution are self-evident. Additional savings at the point of steam generation are possible by maintaining top efficiency in the boiler plant.

Recording and Indicating Equipment

Instruments tell the Engineer exactly how the boiler plant is operating, and give him the means for preventing losses due to inefficiency before they occur.

1. Steam flow recorders. These permit accurate determination of total steam generated, and permit a continuous record of steam consumption between separate buildings or separate sections of the same building. Only by having these figures available, is it possible for the operating engineer to determine his over-all boiler efficiency in terms of fuel consumed per pound of steam generated.
2. CO_2 Recorders. CO_2 content of the flue gas gives an instantaneous measure of boiler efficiency. A CO_2 recorder installation gives the operating engineer a means of operating his boilers at maximum efficiency.
3. Recording Pressure Gauges. Records of pressure variations on the boiler provide means of analyzing load variations and equalizing boiler loads, thereby preventing inefficiencies from this source.
4. Brown instruments for recording or indicating temperatures and pressures for any condition are available, providing a complete service for recording and indicating equipment.

Safety Controls for the Boiler Room

The burning of fuels such as oil or gas requires that automatic controls be used to:

1. Guard against unforseen hazards.
2. Provide an automatic program of starting.
3. Protect against flame failure.

The "Protectoglo" principle provides the only real safety protection for large gas fired boilers. Other protective systems are designed to meet the needs of the particular installation whether oil or gas. Every boiler should be protected against the hazards of excessive pressure and low water conditions.

Consult your Minneapolis-Honeywell branch for expert and impartial advice on the problems of control in your boiler room.

CONTROL CIRCUITS

SECTION III

M-H Control Circuits

While the following discussion cannot cover the complete details of the electrical circuits used in various complete control systems, the fundamental characteristics and basic principles of the several "series" wiring schemes will be outlined and schematically illustrated.

Minneapolis-Honeywell electric controls, with the exception of a few purely mechanical units, consist of electric switches, motors, relays or combinations of these devices. As such their construction is designed in terms of the electrical circuit of which they form a part. To effect various functions it has been found necessary to develop several basic control circuits. To distinguish and to classify these, Minneapolis-Honeywell has identified them by series numbers such as Series 10, Series 20, etc.

Thus all Minneapolis-Honeywell Controls of the electrical type are classified in terms of these same series numbers, i. e., Series 10 Controls, Series 60 Controls, etc.

DEFINITIONS

Low Voltage

In automatic control parlance the term low voltage is applied to wiring or devices utilizing potentials (voltages) of 25 volts or less. Since in Minneapolis-Honeywell controls the standard maximum voltage of low voltage circuits is 25 volts, this general specification is not restated in the catalog description of each control. However, where ratings varying from this standard are in effect special mention is made. Most Minneapolis-Honeywell low voltage units operate on a 20 or 24-volt supply. Low voltage current for control circuits is normally supplied by special control transformers furnished with the control equipment.

Line Voltage

This term refers to the normal voltage of the electrical supply mains and is usually 110 or 220 volts. Line voltage circuits may be connected to the primary circuits of step-down control transformers and thus provide the primary source of power for low voltage circuits. Control units are also designed to operate from or switch line voltage circuits directly. The term high-voltage is sometimes used in place of line voltage but is confusing due to its use as referring to potentials of over 500 volts in connection with commercial electrical distribution systems.

Two-wire

The term "two-wire" is sometimes used to identify wiring circuits or control devices in which two wires or conductors are used in interconnecting the individual units. Switch construction in such control is normally of single pole, single throw mercury switch or open contact design.

Three-wire

As in the case above, this term refers primarily to the number of wires or conductors used in the interconnecting circuits. Three-wire circuits permit of several different switch constructions the details of which will be outlined in later paragraphs.

Holding Circuit

This term applies to a secondary circuit normally energized subsequently to some primary circuit and used to maintain some electrical status quo until a definite and predetermined change has taken place. Holding circuits are usually associated with magnetic relay action. Thus, as a relay is energized by some primary switching action and its armature moves to a closed position, a holding circuit is established which maintains the relay in energization until some predetermined switching action opens the holding circuit. The holding circuit is not, in itself, capable of closing the relay, this being a function of the primary or starting circuit.

Maintaining Switch

The maintaining switch is associated with motor power units of the two-position type. Like the holding circuits in relays, the maintaining switch does not institute operation in the power unit, but this operation once started by some primary circuit is maintained through definite limits by the maintaining switch.

Potentiometer

A number of turns of resistance wire usually arranged on a spool or bobbin and constructed for three-wire connection as shown below, is called a potentiometer.

Schematic Wiring Diagram

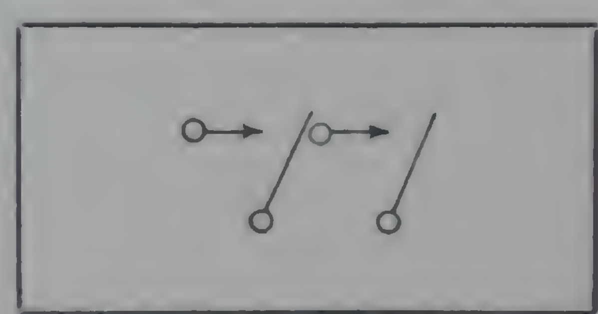
In control circuits the center connection is a movable blade riding over the length of the wound resistance wire and, in turn, actuated by some automatic mechanical or manual means.

Balancing Relay

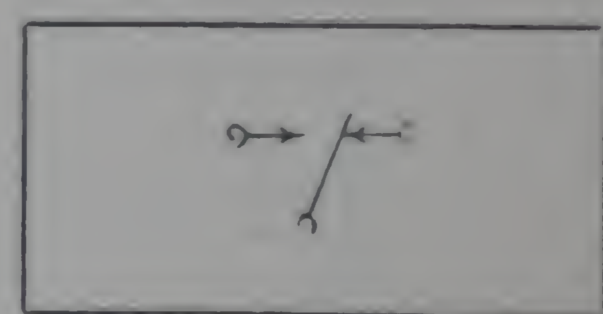
A relay armature (usually provided with electrical contacts) which is acted on magnetically by the effects of two electro-magnetic coils is classified as a balancing relay. As the magnetic effect of these coils is changed in the control circuits the armature moves to position itself as dictated by the stronger coil. Thus, the armature balances itself in accordance with the comparative strength of the coils and changes position to a new balance whenever the coil effect changes.

In Contacts and Out Contacts

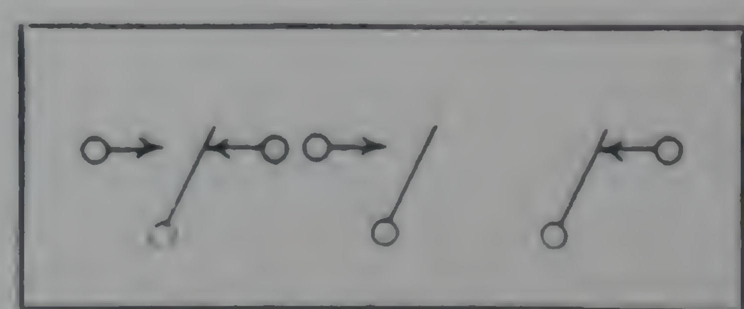
In relays those contacts which are completed when the relay armature is "pulled in" to its energized position are called "in contacts." Similarly contacts which are completed when the relay armature "drops out" to its de-energized position are called "out contacts." It is the standard practice in making Minneapolis-Honeywell control wiring diagrams to show these contacts in the following manner and diagrams always show the relay armature in the de-energized position unless especially marked.



"In Contacts" of a double pole single throw relay



A single pole double throw relay—one "in" and one "out" contact



A three-pole relay in which one pole is for a single pole double throw and two poles are single pole single throw. Of these last two poles one is energized when the relay pulls "in," the other energized when the relay drops "out"

SERIES 10* CONTROL CIRCUIT

ADVANTAGES OF SERIES 10

The Series 10 low voltage control circuit is most widely utilized in the control of:

1. Oil Burner, Gas Burner and Stoker Systems.
2. Commercial Refrigeration Systems.
3. Unit Heaters.

It has several distinct advantages which make it particularly adaptable for these types of installations.

"Fail Safe" Protection

Many types of equipment such as Oil Burners, Gas Burners and Stokers, may constitute a definite hazard if allowed to operate continuously over an extended period of time. Series 10 controls definitely stop the fuel supply to such equipment in the event of a power failure or circuit disorder which renders the control system inoperative.

Elimination of Arcing Contacts

Vibration at or near the control unit will frequently cause chattering and arcing contacts. The Series 10 double blade switching action eliminates this condition.

Flexibility of Adjustment

Series 10 controls permit independent adjustment of "cut-on" and "cut-off" points.

Positive Differential

Short cycling is common in single contact control equipment. The Series 10 holding circuit insures a positive differential between "cut-on" and "cut-off" points.

This feature is of importance in many control sequences such as the provision for a positive defrosting cycle for commercial refrigeration systems.

The full scope of Series 10 advantages may be better appreciated after an analysis of the equipment and circuit principles has been made.

SERIES 10 EQUIPMENT

The basic Series 10 circuit consists of a combination of a controller unit with a relay, motorized valve or solenoid valve which is constructed with a special holding circuit. This basic arrangement may be broadened to include limit controls should they be required.

Controllers

Series 10 controllers may take any of the following forms:

1. Room Thermostats.
2. Insertion Thermostats.
3. Pressure Controllers.

These units are constructed with two separate blades. The blades engage their respective contacts sequentially as the controlled element reaches a predetermined level. They break away from these contacts in reverse sequence as the controlled conditions return to a satisfactory level.

Relays

Series 10 relays are of electro-magnetic construction and are provided with:

1. Low Voltage operating circuits.
2. Low Voltage holding circuits.
3. Built-in transformers.
4. Line Voltage Switching circuits.

Low voltage current for the operating and holding circuits of Series 10 relays is provided from transformers built into the relay cases. Current is supplied continuously unless special provision for manual shut down is made.

When both controller blades are engaged with their respective contacts the relay operating circuit is completed, and the magnetic relay coil is energized. The holding circuit is established through the subsequent switching action.

Switching effect is obtained by attaching contacts to the movable relay armature. As the magnetic effect of the field coil displaces this armature the contacts are engaged. Series 10 relay armatures are equipped with two separate contact mechanisms:

1. To close the low voltage holding circuit.
2. To complete a line voltage circuit to the load under control (usually a motor).

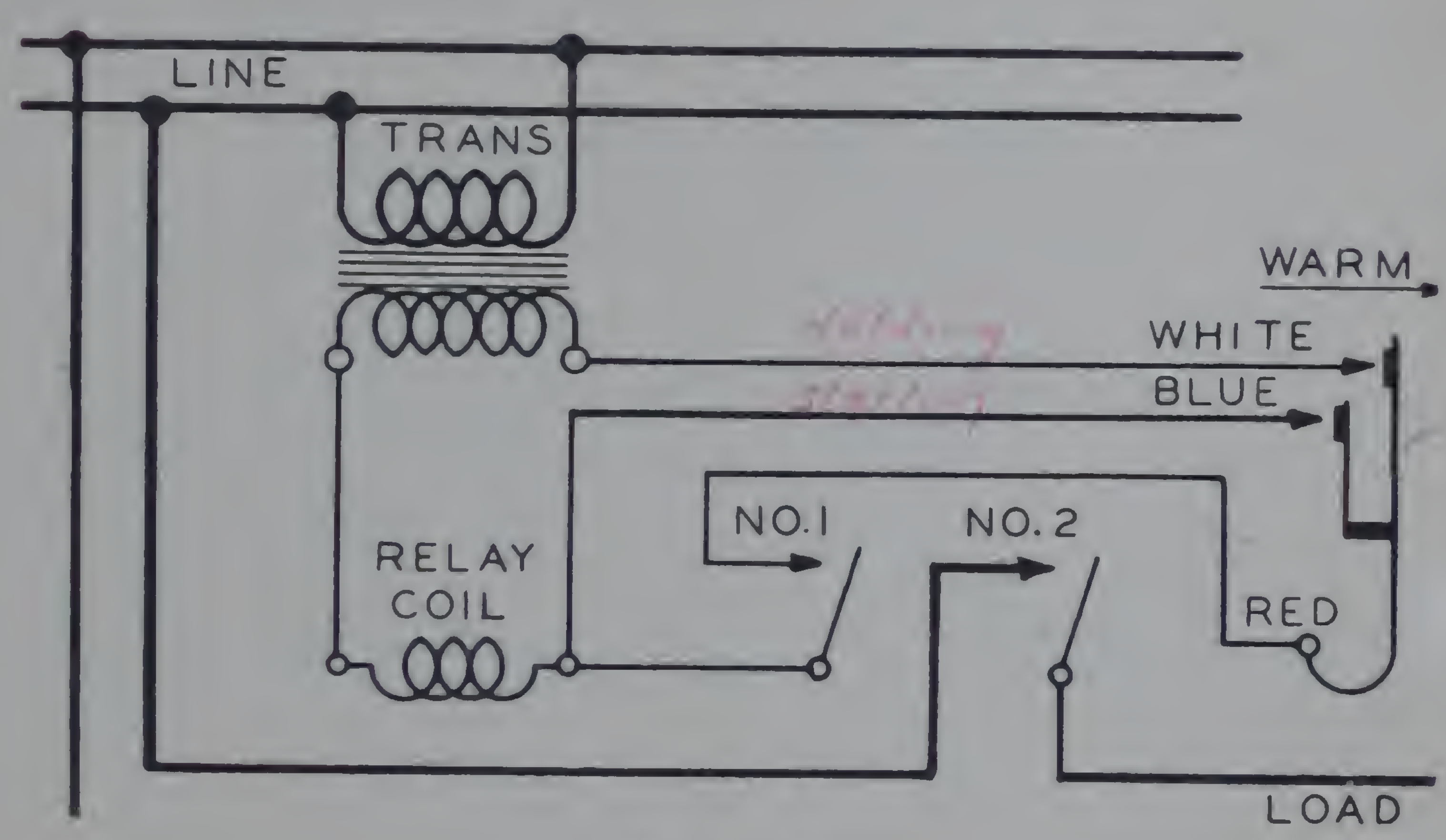


Figure 1

Fig. 1 illustrates a complete Series 10 control circuit. The equipment includes:

1. A room thermostat.
2. A relay.

The thermostat is in a satisfied position and both contacts are open. The flexible blade is arranged to make contact with the white control terminal and the rigid blade with blue.

Contacts 1 and 2 are attached to the relay armature and switch the holding and load circuits, respectively.

In the diagram line voltage circuits are indicated by heavy connecting lines and low voltage circuits by light lines.

In the following diagrams the complete electrical cycle is illustrated. For purposes of simplification all line voltage circuits have been eliminated. It should therefore be noted that:

1. Current is supplied to the transformer primary continuously.
2. The load contact is closed whenever the relay coil is energized.

It should be further noted that:

1. Solid lines indicate wires through which current is passing
2. Dotted lines indicate inactive circuits.

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SERIES 10* CONTROL CIRCUIT

Thermostat Satisfied

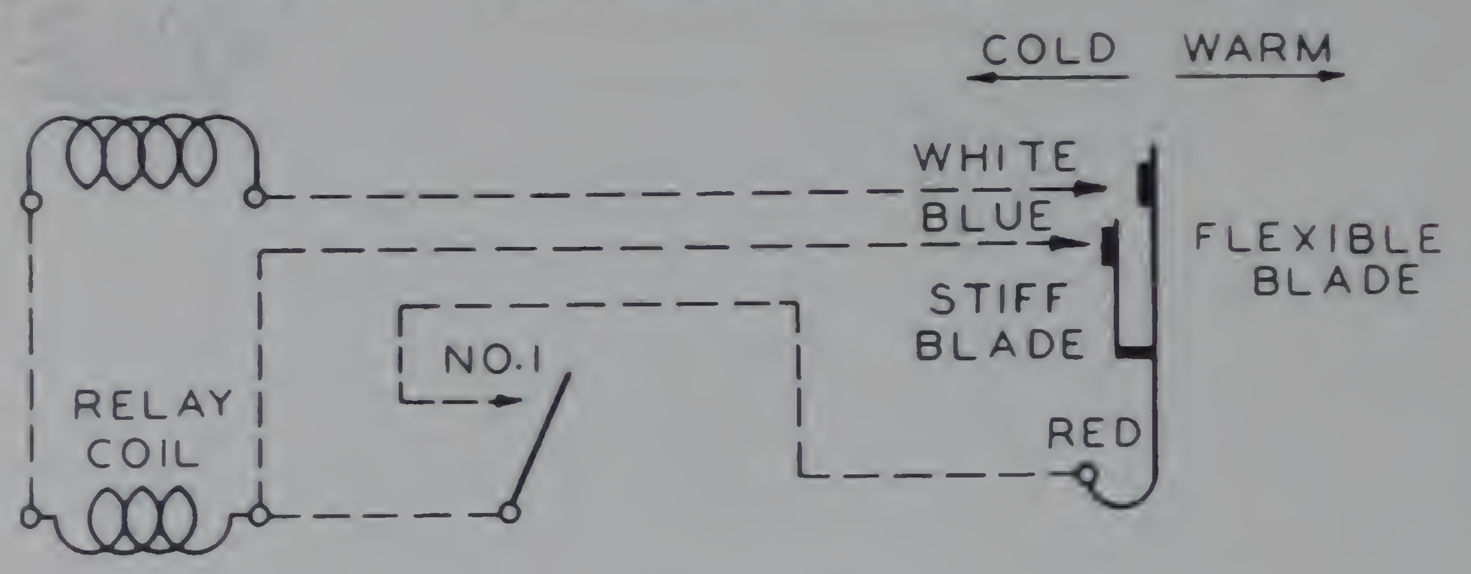

Figure 2

When the thermostat is at or above the control point:

1. Both thermostat blades are open.

2. There is no closed path of current, and no current is flowing.

Slight Temperature Drop

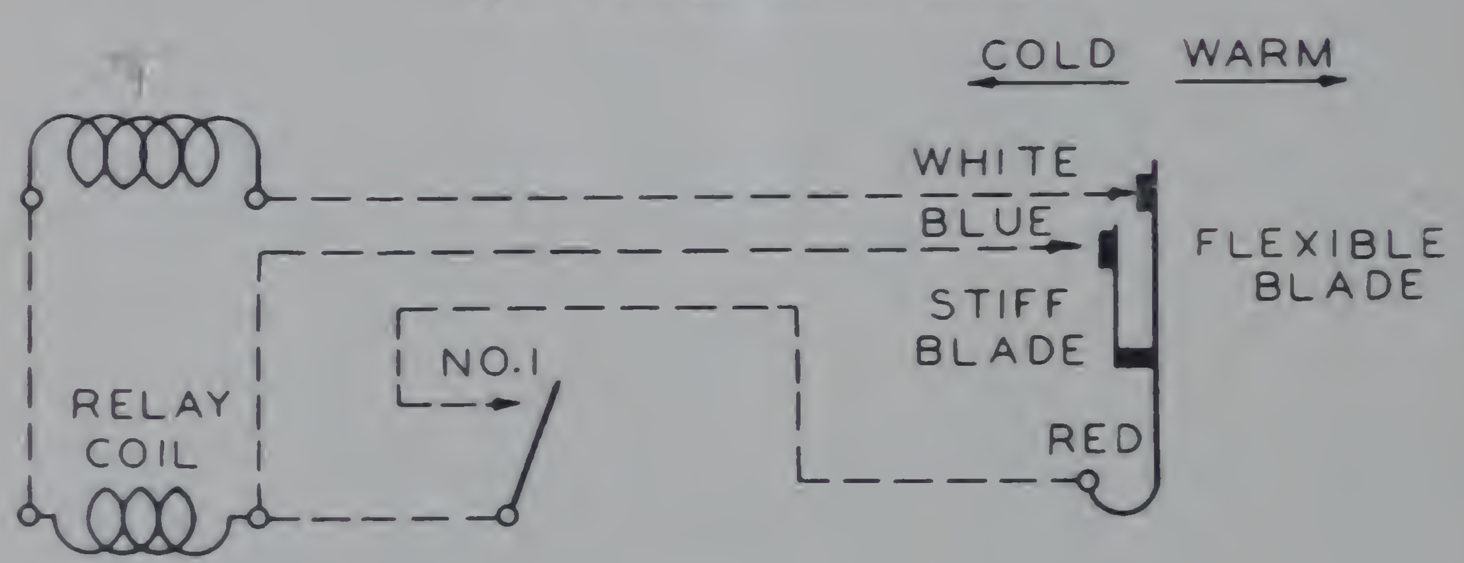

Figure 3

On a slight drop in temperature:

1. The flexible blade engages the W contact.

2. There is still no closed path of current.

Further Temperature Drop

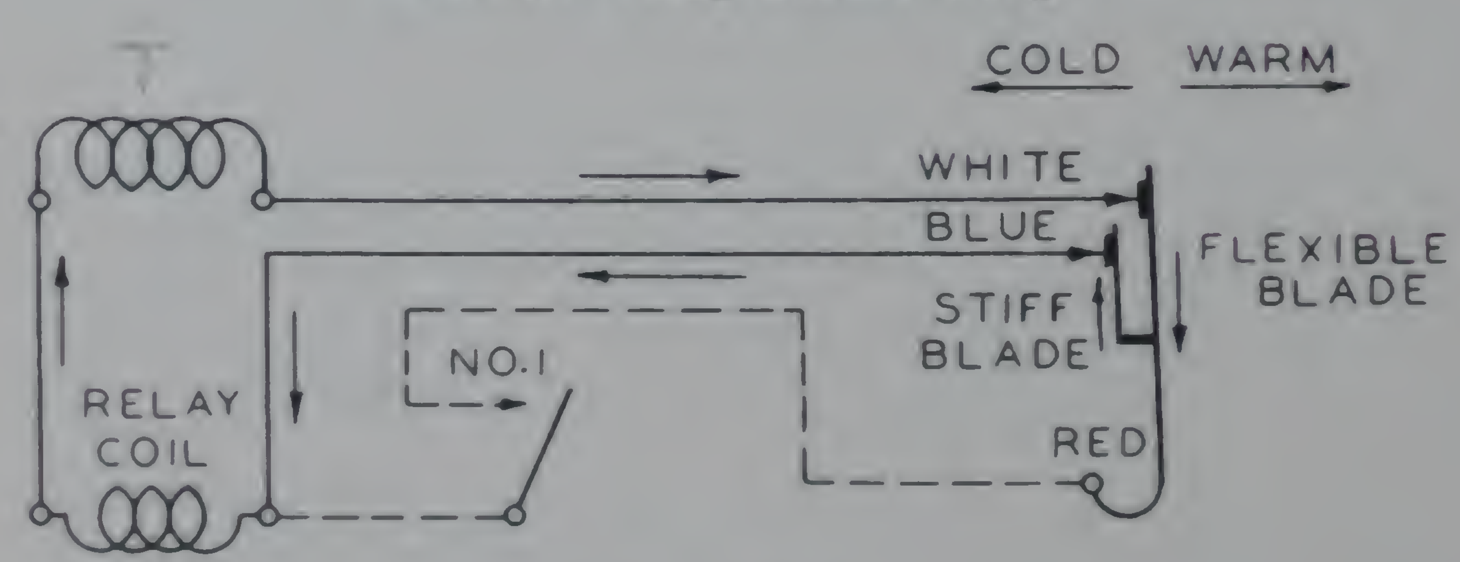

Figure 4

On a further temperature drop:

1. The rigid blade engages the B contact.

2. The operating circuit (as shown by solid lines and arrows) is established.

3. The relay coil is energized.

Holding Circuit Established

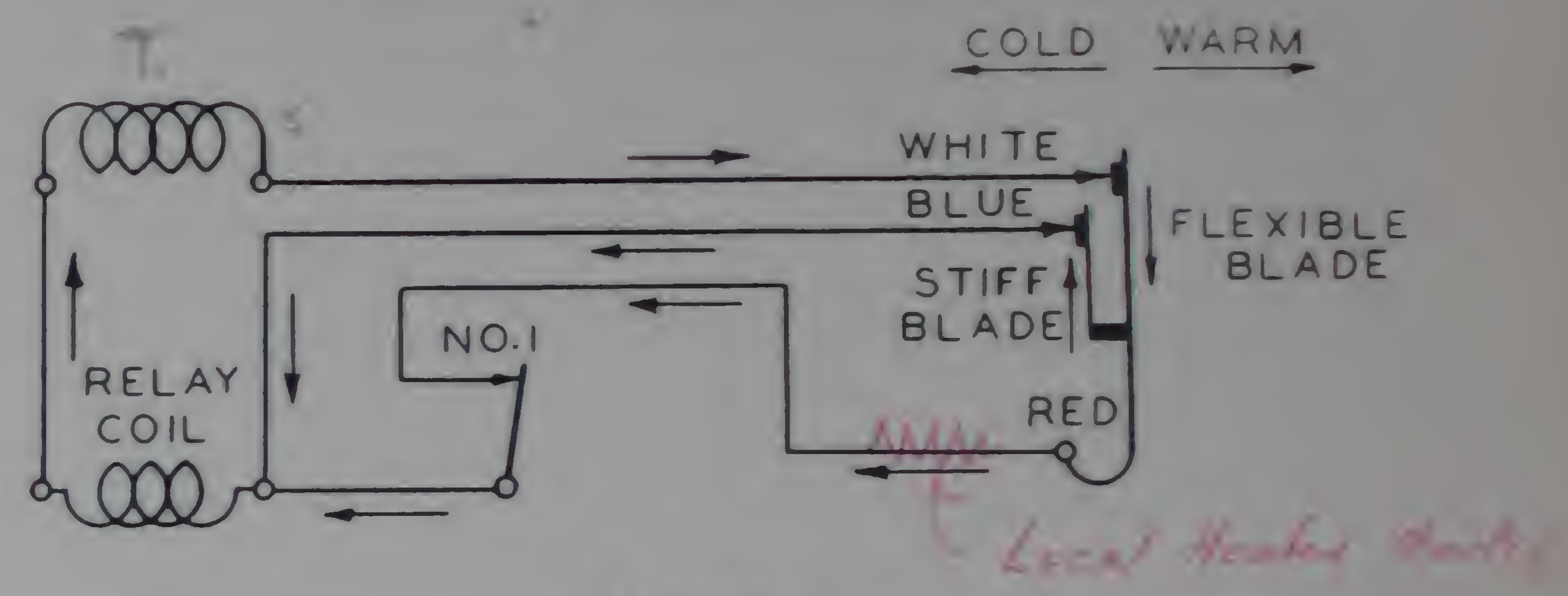

Figure 5

When the relay coil is energized:

1. The armature is pulled "in" and contact number 1 is closed completing a second circuit as shown in Fig. 5.

2. Contact number 2 (not shown) is closed and the load circuit completed.

Slight Rise in Temperature

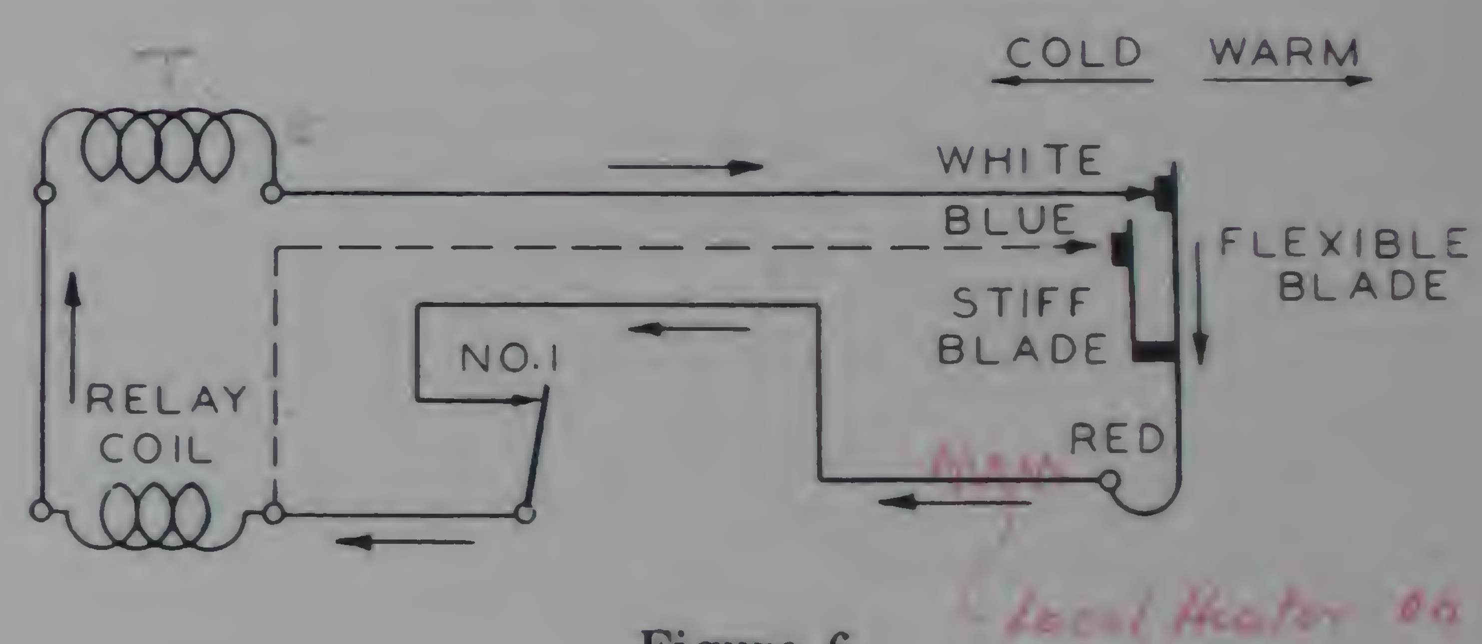

Figure 6

As the temperature rises slightly:

1. The rigid blade breaks from the B contact.

2. The operating circuit (see Fig. 4) is de-energized.

3. The holding circuit is still active and current flows through W-R, contact number 1 and the relay coil.

4. The relay coil is still energized.

5. The armature is held "in" and the load contact is still closed.

Further Rise in Temperature

On a further rise in temperature the flexible blade breaks its contact with W:

1. All circuits are inactive (see Fig. 2).

2. The relay is de-energized and the armature drops "out."

3. The load circuit is broken.

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SERIES 20* CONTROL CIRCUIT

Advantages of Series 20

The Series 20 control circuit has been designed to provide low voltage two-position control of:

1. **Motorized Valves.**
2. **Motorized Dampers.**

Series 20 controls are arranged to make one circuit to start and a second separate circuit to stop. They should not be used on applications where continued operation in the event of power failure would constitute a hazard.

A basic Series 20 control circuit may be obtained by combining a controller with a single pole double throw switching action and a Series 20 control motor. Limit controls may be added where required.

SERIES 20 EQUIPMENT

Controllers

Series 20 controllers may take the form of:

1. **Room Thermostats.**
2. **Insertion Thermostats.**
3. **Humidity Controllers**
4. **Pressure Controllers.**

Each controller is constructed with a single pole double throw switching action. Controllers may be of the open contact type or the mercury switch type. In either case one circuit is made on a rise in the condition of the controlled element, and a second separate circuit is made on a drop.

Motor Units

Series 20 power units may be adapted, through linkages, to either valve or damper equipment. They are constructed with:

1. **A uni-directional electric motor operating on low voltage.**
2. **Gear trains to provide power at the end of a drive shaft.**
3. **A maintaining switch.**

Since the electric motor unit rotates in only one direction the linkage mechanism must be arranged to exert a force in one direction during one-half of the drive shaft rotation, and in the opposite direction during the second half of the rotation. Likewise, if two-position operation is to be obtained, special provision must be made to:

1. **Stop the motor at the end of each ½ revolution.**
2. **Prevent the motor from stopping at any point in its travel except the two ½ revolution extremes.**

These limiting functions are accomplished through the use of a special type of maintaining switch built into the power unit. This switch consists of a cam fastened to the drive shaft of the power unit and two sets of electric contacts. As soon as the motor operating circuit has been completed by the controller action the cam acts to close a contact and establish a holding circuit. This circuit is maintained until the shaft has rotated through 180 angular degrees and is then broken. Thus the motor once started cannot stop until it has completed one-half of its complete cycle.

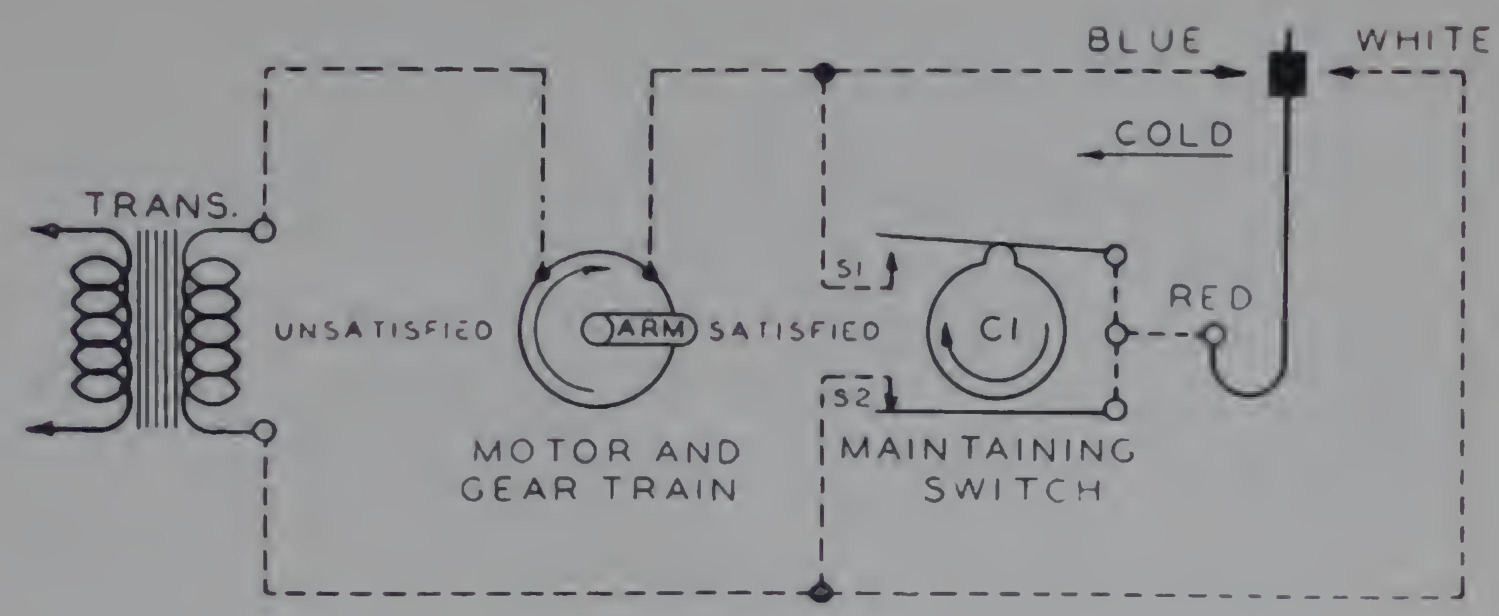

Figure 1

Fig. 1 illustrates a complete Series 20 control circuit. The equipment used includes:

1. **Open contact thermostat.**
2. **Series 20 motor.**
3. **Step-down transformer.**

The thermostat is constructed with a bimetal blade which engages the blue contact on a drop in temperature, and the white contact on a rise. It is shown in a satisfied position in Fig. 1.

The maintaining switch cam and contacts are shown schematically, as is the motor, gear train and crank arm.

The following diagrams show the progressive completion of the various circuits. Solid lines indicate wires carrying current, dotted lines those which are inactive.

Drop in Temperature

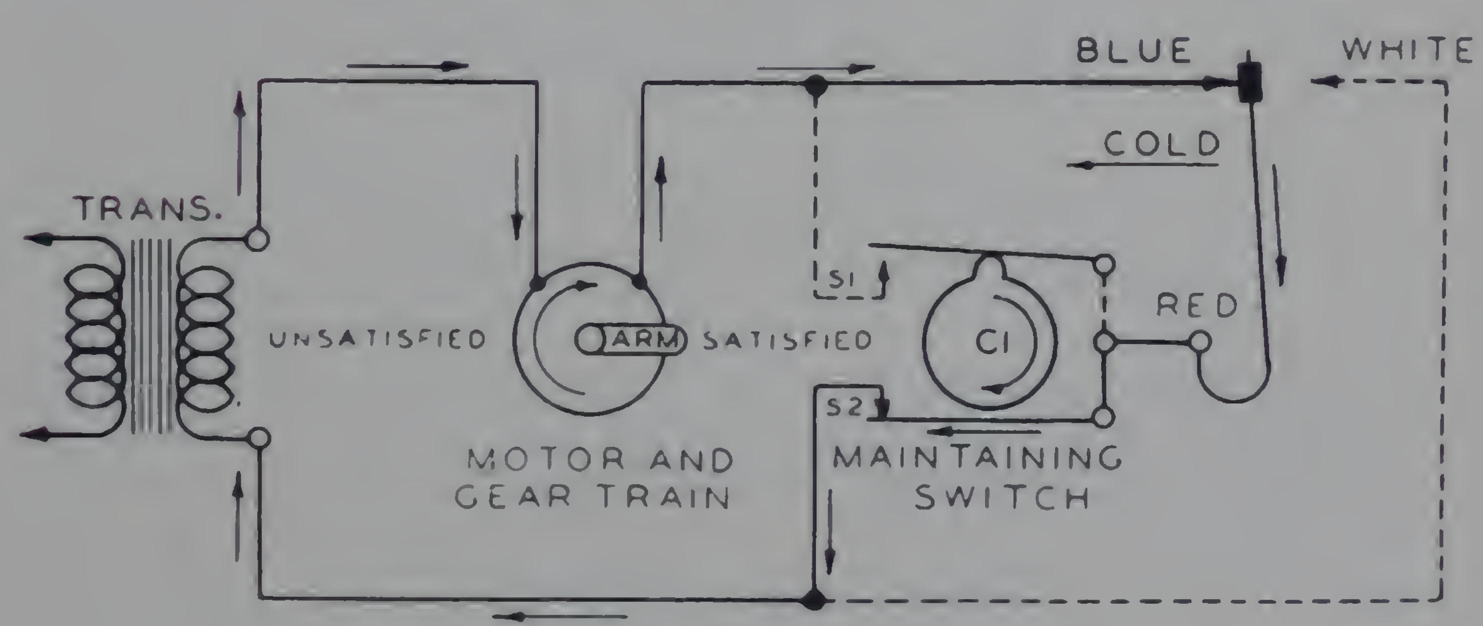

Figure 2

On a drop in temperature:

1. The thermostat blade engages the B contact.

2. A circuit is completed as shown by the solid lines and arrows.

3. The motor is energized and starts to rotate the shaft in a clockwise direction.

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SERIES 20* CONTROL CIRCUIT

Maintaining Circuit Established

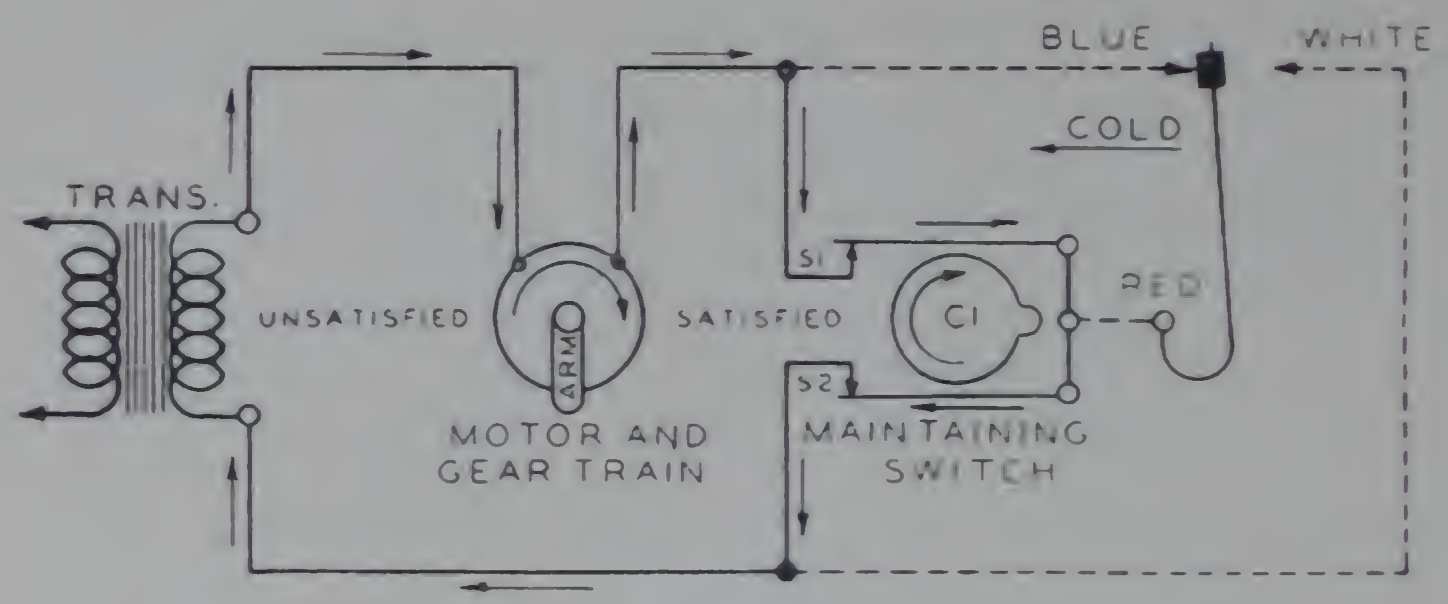

Figure 3

The maintaining switch cam rotates with the drive shaft and closes contact S_1.

1. A circuit is established through S_1 and S_2. This circuit is independent of the thermostat and will maintain the current to the motor regardless of action at the thermostat.

2. If the thermostat blade remains engaged with the B contact a small amount of current will continue to pass through it. Due to increased resistance in this path, however, the balance of the current will pass through the maintaining circuit.

Maintaining Circuit Breaks

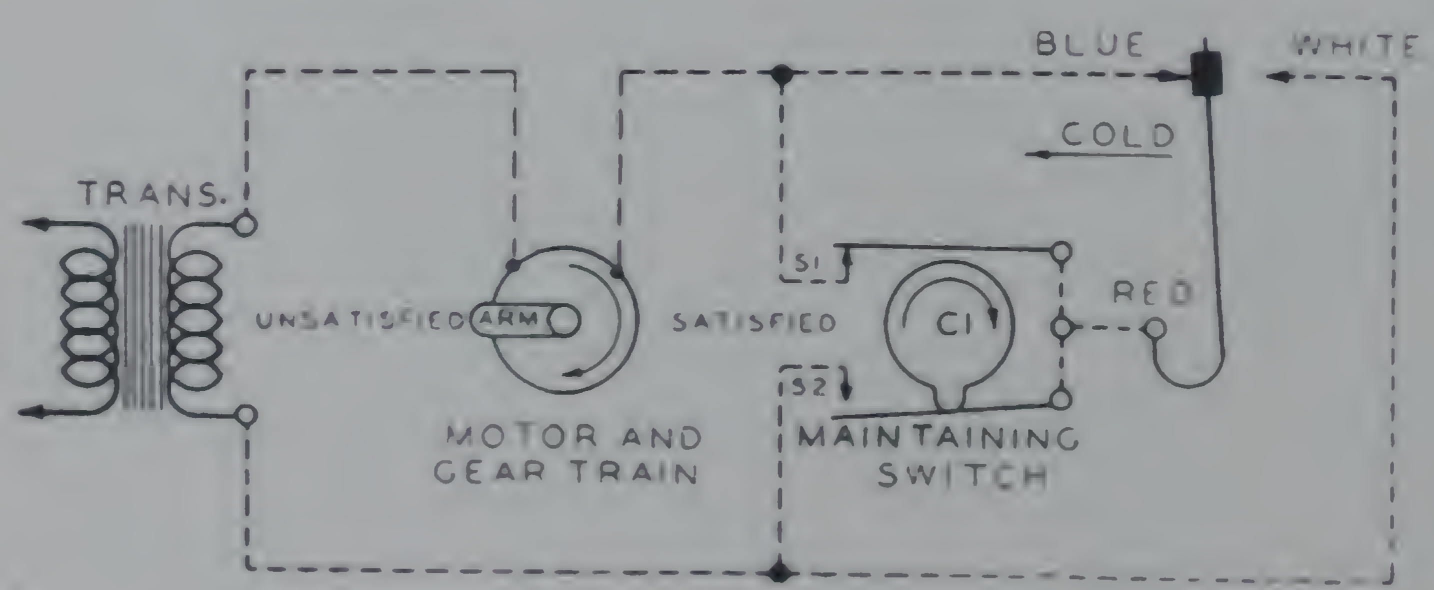

Figure 4

When the motor shaft has rotated 180 angular degrees the cam breaks contact S_1 of the maintaining switch.

1. All circuits are now incomplete.

2. The motor stops.

Rise in Temperature

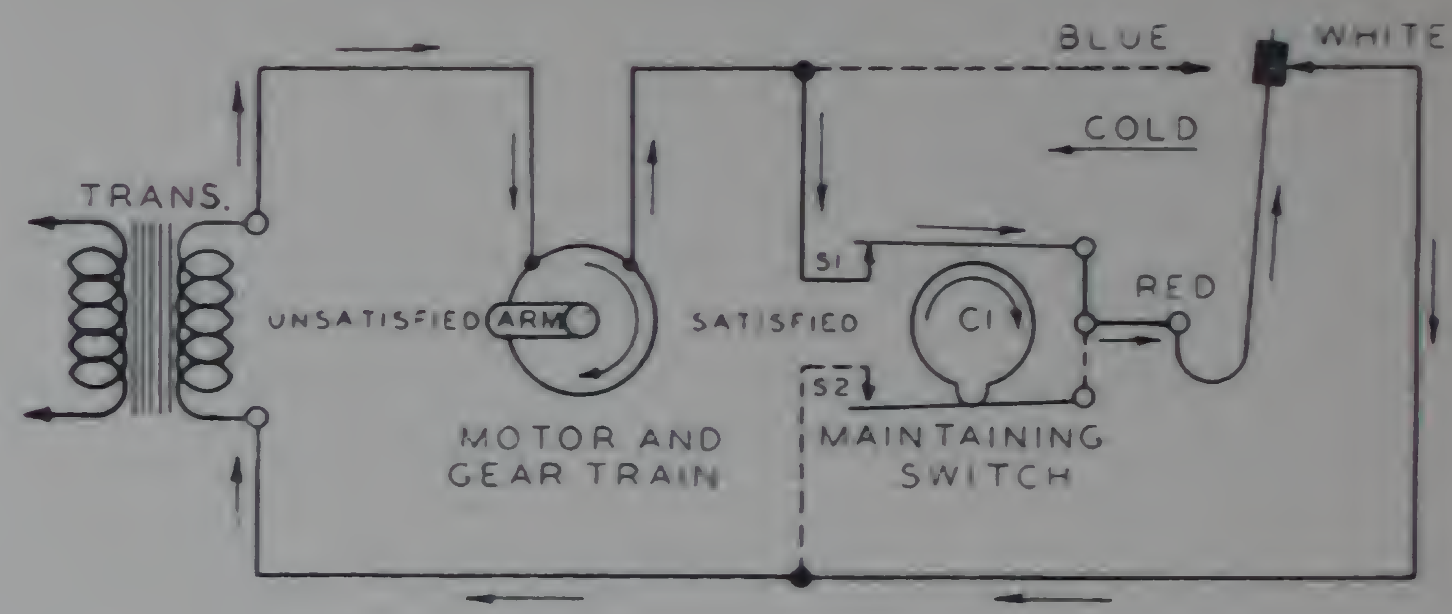

Figure 5

On a rise in temperature the thermostat blade moves to the right and engages the W contact:

1. A starting circuit is completed as shown.

2. The motor starts to rotate in a clockwise direction.

Maintaining Circuit Re-established

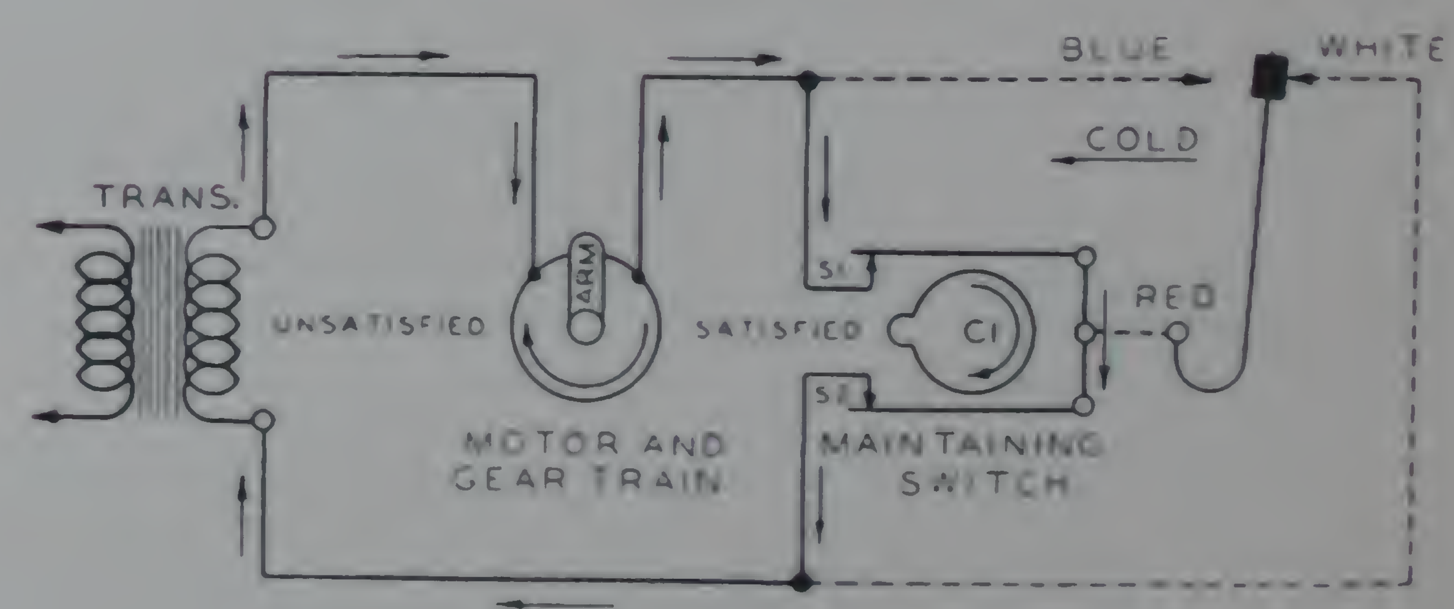

Figure 6

As the shaft rotates switch S_1 is closed by the cam and the maintaining circuit is re-established.

When the motor has completed a 180° revolution the maintaining circuit is again opened (see Fig. 1) and the motor stops. It has now finished a complete cycle.

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SERIES 30* CONTROL CIRCUIT

SERIES 30 APPLICATION

Low voltage Series 30 control equipment may be used for any application where it is necessary to:

1. **Operate relays from single pole double throw controller units.**

Series 30 control equipment is partially but not completely "fail-safe" in its operation. In the event of a general power failure a relay of this construction will be automatically de-energized. However, should a control circuit disorder develop it is possible to lock the relay in an energized position for an indefinite period of time. For this reason Series 30 control application is not recommended for installations where continued operation might constitute a hazard.

A complete Series 30 control circuit may be obtained by combining any Series 20 controller with a special relay of Series 30 construction.

SERIES 30 EQUIPMENT

Controllers

Any Series 20 controller of either open contact or mercury switch type construction may be used.

Relays

Series 30 relays include:

1. **Separate low voltage starting and stopping circuits.**
2. **Low voltage maintaining circuit.**
3. **Built-in transformers.**
4. **Line voltage load contacts.**

Since Series 30 relays are constructed to operate with Series 20 controllers, special provision must be made to provide separate starting and stopping circuits. This is accomplished by using two magnetic coils. One coil is utilized to produce the magnetic force required to pull in the movable armature. The second coil, energized by the stopping circuit, produces an equal magnetic effect but is wired in such a manner that it will oppose the effect of the first coil. This opposition of forces will neutralize the total magnetic effect upon the armature and allow it to drop out.

SERIES 30 OPERATION

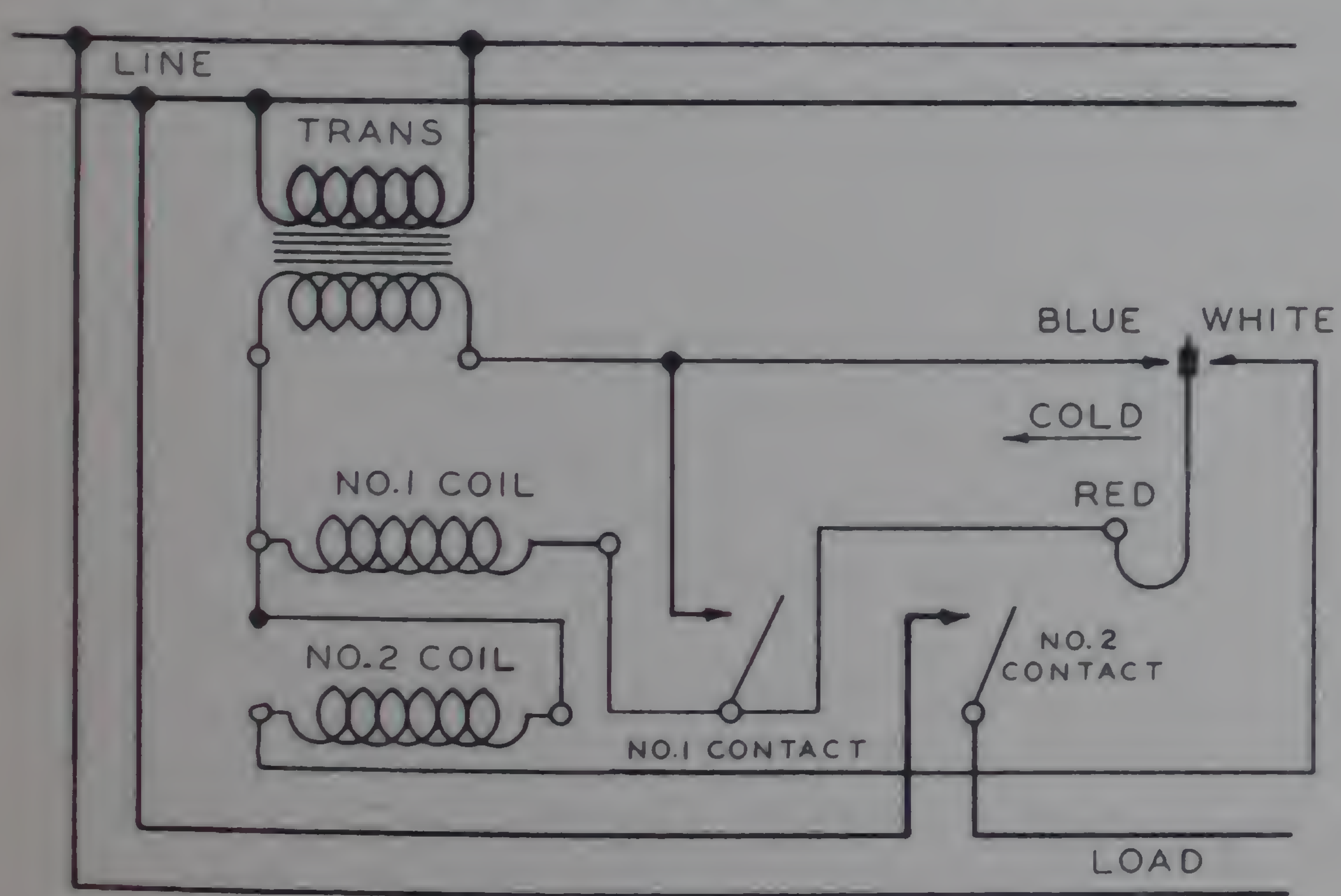

Figure 1

Fig. 1 illustrates a complete Series 30 control circuit. The equipment utilized includes:

1. **A Series 20 open contact room thermostat.**
2. **A Series 30 relay.**

The thermostat is shown in a satisfied position and all circuits are de-energized.

Coil number 1 is energized to pull the armature into a closed position and coil number 2 provides the bucking effect required to de-energize the relay.

Contact number 1 is used to complete the relay holding circuit and contact number 2 is used to switch the load under control (usually a motor). Contacts number 1 and 2 are attached to the movable armature in a manner similar to that described under the discussion of Series 10 relays.

The following diagrams illustrate the progress of circuit action on a change in temperature at the thermostat. Solid lines indicate wires through which current is passing; dotted lines indicate inactive circuits.

In order to simplify the explanation, all line voltage circuits have been omitted and it should be noted that:

1. **Current is supplied continuously to the control transformer.**
2. **The load contact is closed whenever coil number 1 is energized.**

Temperature Drop

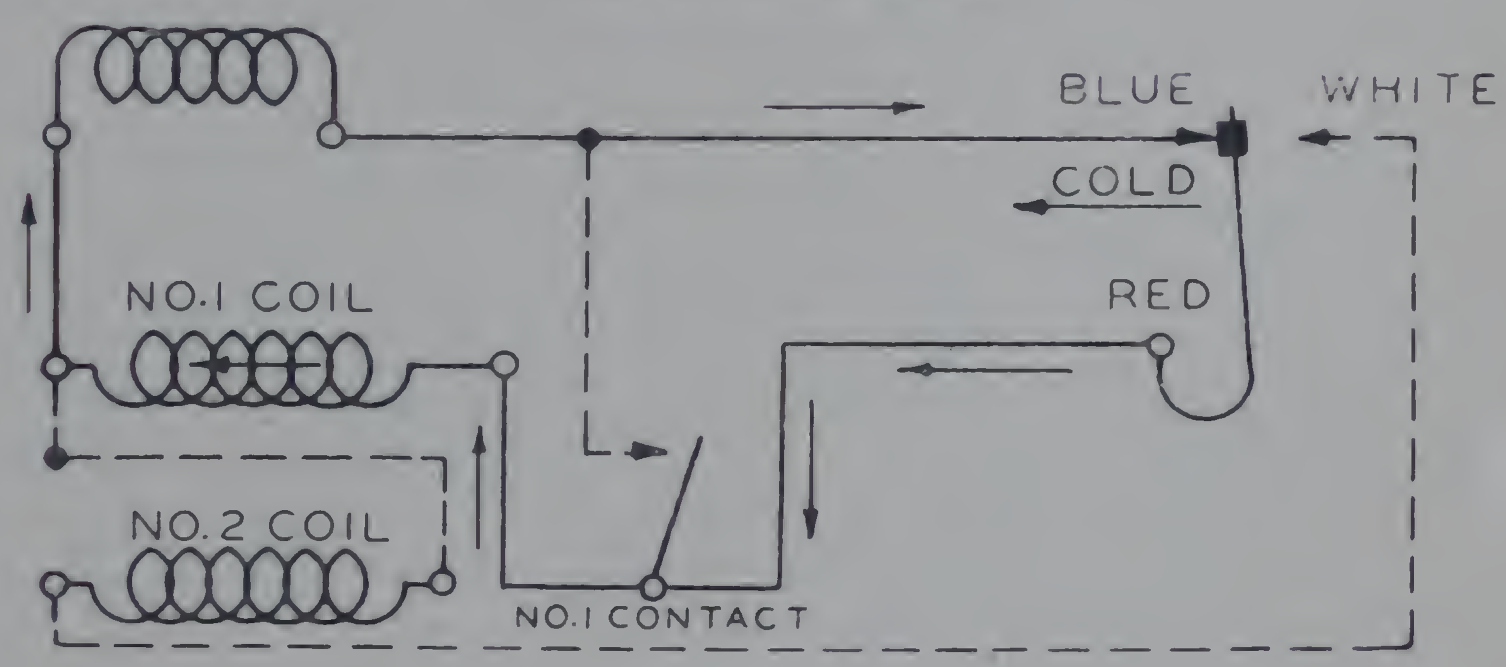

Figure 2

On a drop in temperature the blade of the Series 20 thermostat moves to the left and engages contact "B".

1. A circuit is completed as shown by the solid lines and arrows.
2. Coil number 1 is energized.

Holding Circuit Established

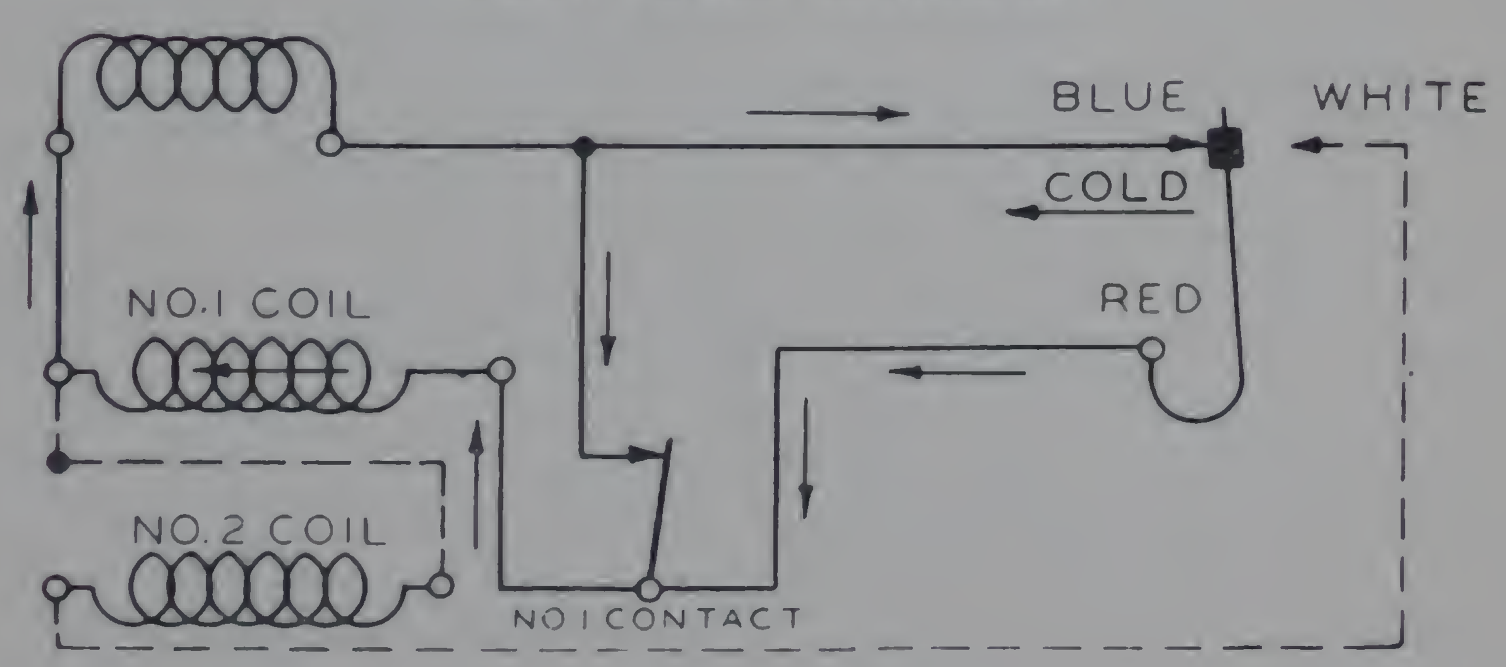

Figure 3

As coil number 1 is energized, the relay armature is pulled in.

1. Contact number 1 is closed and a direct circuit from the transformer through contact number 1 and coil number 1 is established. This new circuit constitutes the holding circuit.

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SERIES 30* CONTROL CIRCUIT

Slight Temperature Rise

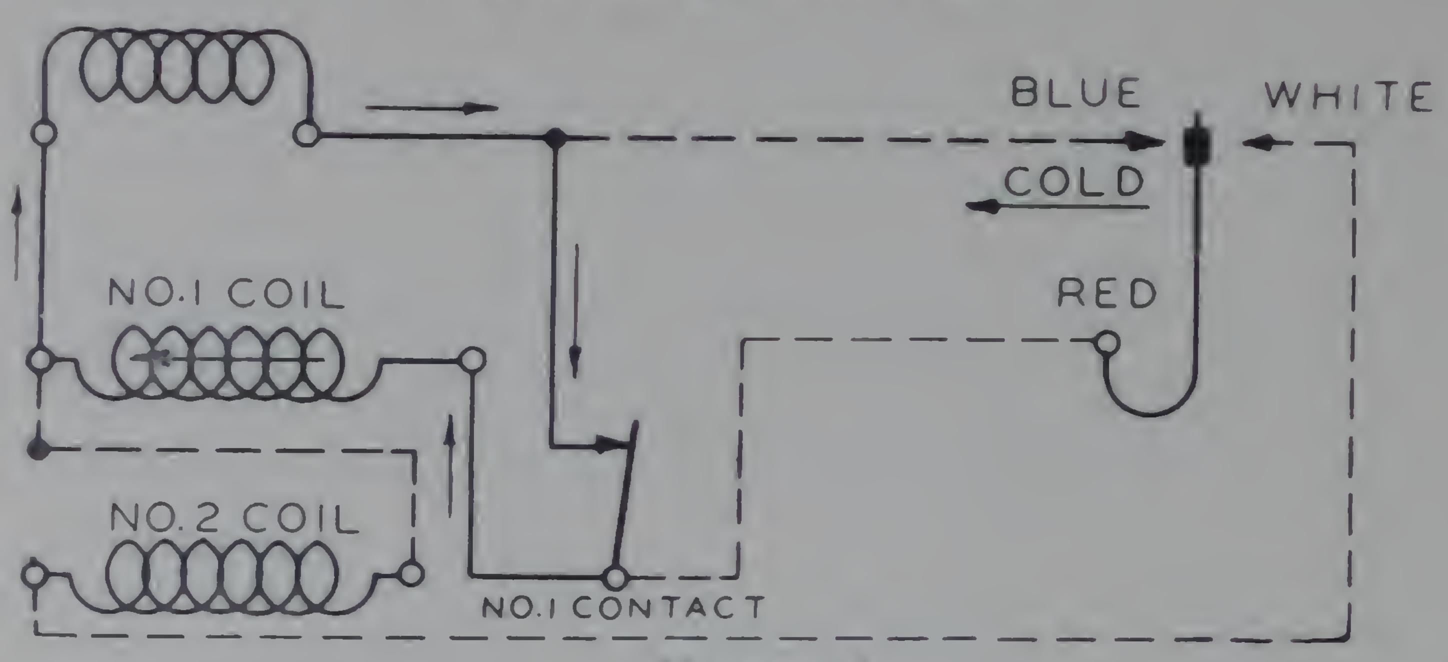


Figure 4

In response to a slight rise in temperature:

1. The thermostat blade moves to the right away from contact "B".
2. The starting circuit (shown in Fig. 2) is opened.
3. The holding circuit remains energized.
4. The armature is held in place and contacts number 1 and 2 remain closed.

Further Temperature Rise

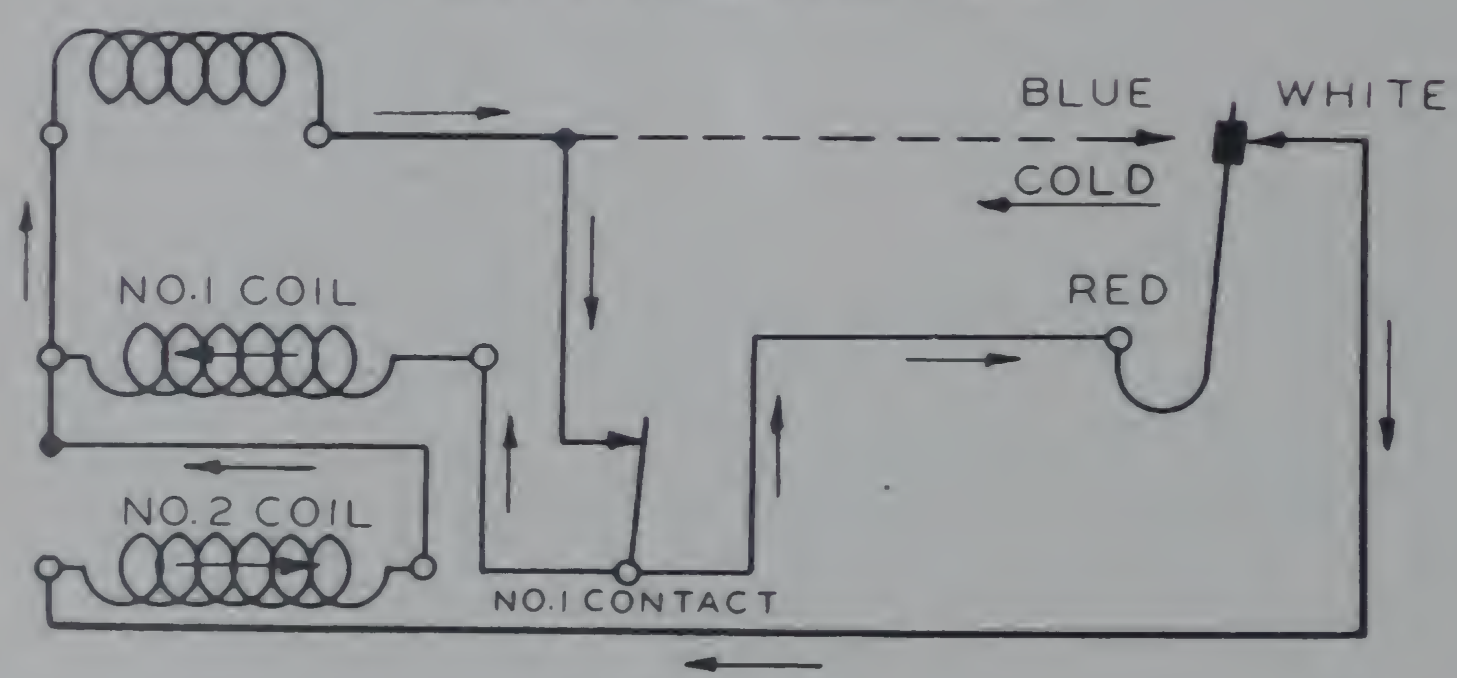


Figure 5

As the temperature continues to rise: (Fig. 5)

1. The thermostat blade moves to the right and engages with contact "W".
2. A circuit is established through the thermostat and coil number 2 as indicated by solid lines and arrows.
3. Coil number 2 is energized and neutralizes the effect of coil number 1.

Holding Circuit De-energized

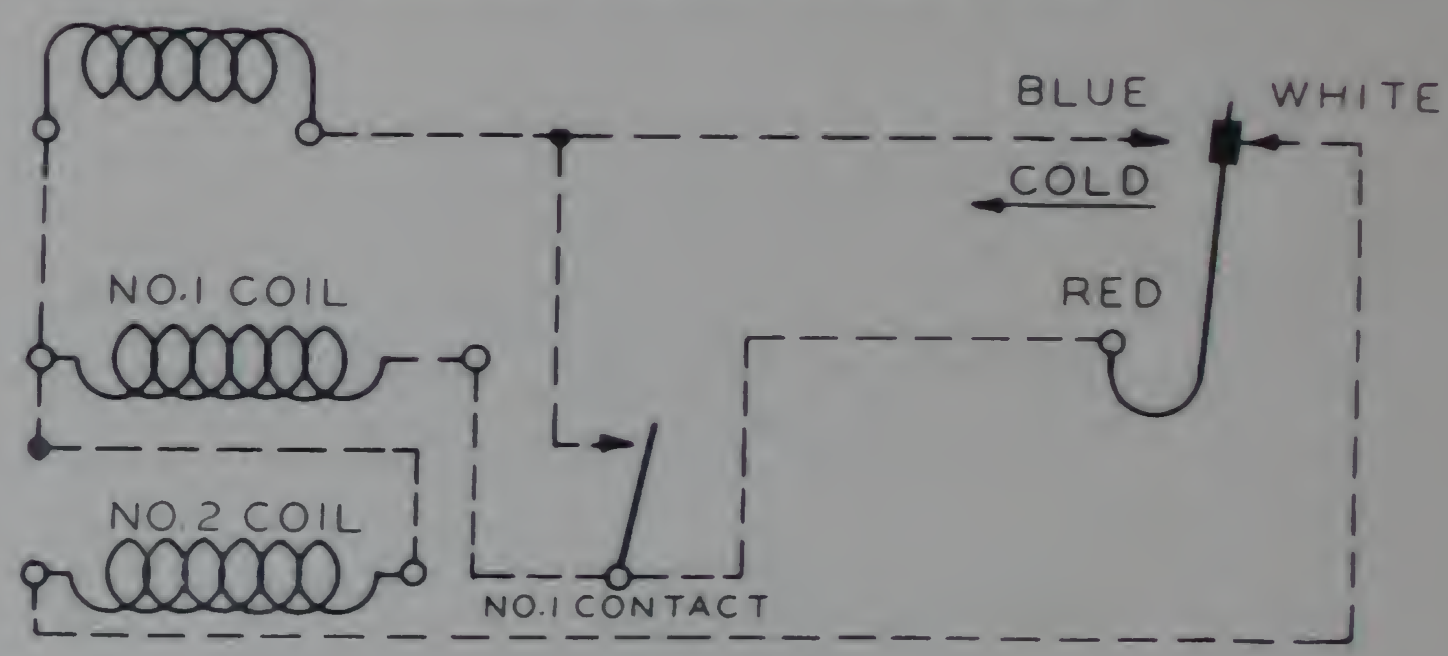


Figure 6

As the magnetic effect of coil number 1 is neutralized by coil number 2:

1. The armature drops out.
2. The holding and load circuits are broken.
3. All equipment is de-energized.

SERIES 40* CONTROL CIRCUIT

SERIES 40 APPLICATION

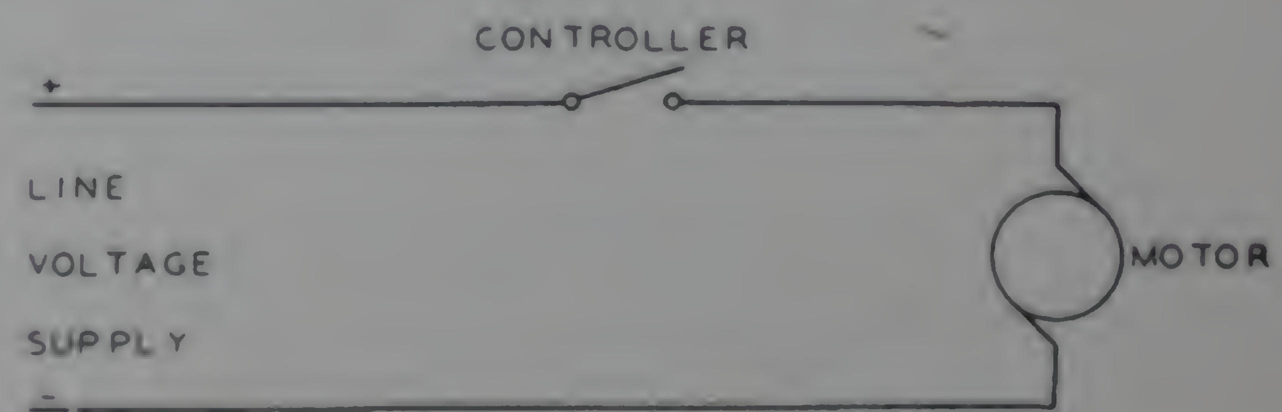
"Series 40" is the term used by Minneapolis-Honeywell in classifying the electrical construction which permits the switching of line voltage electrical loads by means of a single pole single throw contact mechanism. In the operation of Series 40 circuits the load, such as a motor, relay, resistance or lights, is energized when the switch is closed and is de-energized when the switch is open. This arrangement is, of course, the simplest in principle. Normally in control use, the Series 40 controllers operate the load directly, but in the instance of loads that exceed the rating of the controller, a simple intermediate relay may be inserted between the controller and the load. A further variation occurs in circuits where the load requires double or triple pole switching, in which case the single pole single throw controller may operate the closing coil of an intermediate relay, the load contacts of which may be adapted to the requirements of the load.

Series 40 controllers always operate at line voltage and therefore require wiring enclosed in conduit or armored cable (BX). Wiring costs with Series 40 thus tend to be higher than with low voltage systems if long runs of wiring are involved. However, in the case of short runs or where the conduit may be run exposed, the added wiring cost may be less than the cost of reducing the control circuit to low voltage by means of a transformer.

Series 40 control is another variety of two-position or on-and-off control and involves two-wire control circuits.

Series 40 relays consist of a pilot operated at line voltage which operates an armature carrying one or more "in" or "out" contacts capable of operating the load.

A simple Series 40 circuit is shown below.



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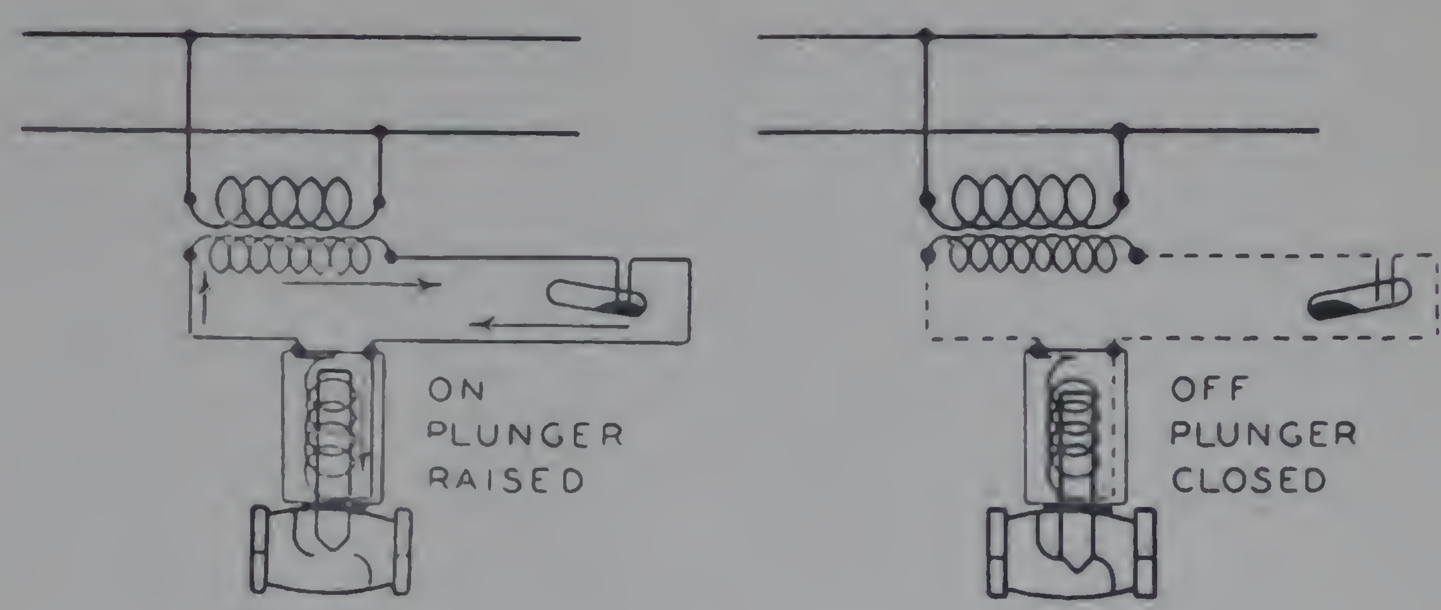
SERIES 80* CONTROL CIRCUIT

SERIES 80 APPLICATION

There are applications of control requiring two-position operation in which it is desirable that low voltage two-wire controller circuits be utilized. The principal reason for the low voltage requirement is the lowered cost of installing the controller wiring, particularly on long runs. The reason for the two-wire controller circuit is to permit control from units involving single pole single throw contact mechanisms.

The Minneapolis-Honeywell circuit which provides low voltage two-wire on-and-off control is the Series 80 Circuit. The principal units of the Minneapolis-Honeywell line utilizing the Series 80 Circuit are Solenoid valves such as the V837A Water Valves and the M87A Motor. A typical circuit using the Series 80 principle with solenoid valves is illustrated here.



In view of the fact that no holding circuit is used and further because the contact is a single pole arrangement, the controller must be either of the snap acting or mercury switch type in order to avoid super-sensitivity. Slow moving single pole contact mechanisms should be avoided.

SERIES 60* CONTROL CIRCUIT

SERIES 60 APPLICATION

The Series 60 control circuit is similar in its operating effect to the Series 20 discussed on page 5.

The difference between the two circuits lies in the fact that Series 60 control equipment is designed primarily for line voltage application. Because the controllers and power units are required to handle line voltage current, it is necessary that they be constructed especially for this heavy duty type of service.

Series 60 systems are usually applied to:

1. **Industrial applications using line voltage equipment.**
2. **Installations where single pole double throw control of line voltage circuits is required.**

A basic Series 60 circuit may be obtained by combining a controller unit of the heavy duty single pole double throw type with a line voltage control motor. The motor must include a maintaining switch mechanism. This system may be expanded to include limit controls of various types should they be required.

SERIES 60 EQUIPMENT

Controllers

Series 60 controllers may take any of the following forms:

1. **Room thermostats.**
2. **Insertion thermostats.**
3. **Pressure controllers.**
4. **Humidity controllers.**

These control units are usually of the mercury switch type and are designed to provide single pole double throw switching action.

Motor Power Units

Series 60 power units consist of a small motor operating directly from line voltage current. This motor delivers power through a gear train to a drive shaft which may in turn be mechanically interconnected with dampers or valves.

Inasmuch as the desired result is two-position control, it is necessary that the action of the crank arm be divided into two half revolution steps between which the motion shall cease. This action is accomplished through the use of a maintaining switch similar in action to that described under the discussion of Series 20 control units.

SERIES 60 OPERATION

Because of the close similarity between the operating characteristics of the Series 20 and Series 60 circuits, no complete circuit description of the latter has been included.

Although the mechanical construction of the two types of equipment is somewhat different due to the type of service demanded from each, their basic design is almost identical.

For a complete analysis of this fundamental operating circuit, refer to page 5 under the discussion of Series 20 control circuits.

SERIES 60* FLOATING CONTROL CIRCUIT

SERIES 60 FLOATING APPLICATION

The action of this circuit differs from all of those previously discussed in that it does not provide two-position operation. Series 60 floating control is usually applied to:

1. **Motorized valves used on tank level control systems.**
2. **Motorized dampers used for static pressure regulation.**

There are no fixed number of positions in floating control as it is the intent that the load, i. e., valve, damper, etc., be allowed to assume any position from one extreme of motion to the other so long as the controlled factor remains between the limits of the controller.

In further explanation of this operation consider a motorized louvre damper installed in a fan heating system, throttling the supply of air to the fan intake. The damper is controlled by a static pressure regulator which measures the air pressure in the distributing duct. Should the static pressure within the ducts change, the static pressure regulator will measure this change and in turn re-position the louvre damper ahead of the fan and bring the static pressure back within the control range.

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SERIES 60* FLOATING CONTROL CIRCUIT

Whereas under two-position control the louvre damper would be either full open or full closed depending on the amount of pressure in the duct, floating control puts no such limitation on the damper position. Under floating control the damper will stand still in any position which will continuously pass sufficient air to the fan to maintain the duct pressure between the required limits. If the air passing through the damper is insufficient to maintain this pressure and the pressure falls to the lower limit, the controller will open the damper further, thus increasing the air delivery until the pressure returns to some point between the upper and lower limits. If the pressure level is held, the damper will remain stationary, but if the increased delivery of air causes the pressure to rise above the upper limit of the pressure controller, the controller again steps in, this time to cause the damper to move toward the closed position. The damper will, however, move either open or closed only so long as the pressure at the controller is below or above the set limits.

In other words, there is no holding or "maintaining switch" action, hence the damper is not required to run to its limits and can stop anywhere. Thus it is said to "float" between the limits of its travel as the controller holds the pressure between predetermined limits. Some further observations relative to the use of floating control will follow a study of how the equipment and circuits function.

SERIES 60 FLOATING EQUIPMENT

Controllers

Series 60 floating controllers are similar in construction to those used in either Series 20 or Series 60 circuits. They are arranged to provide a single pole double throw switching action and are normally used for low voltage application.

Motor Power Units

The Series 60 floating control motors are constructed with:

1. Reversible capacitor type power units.
2. Limit switches to limit the rotation of the crank arm.

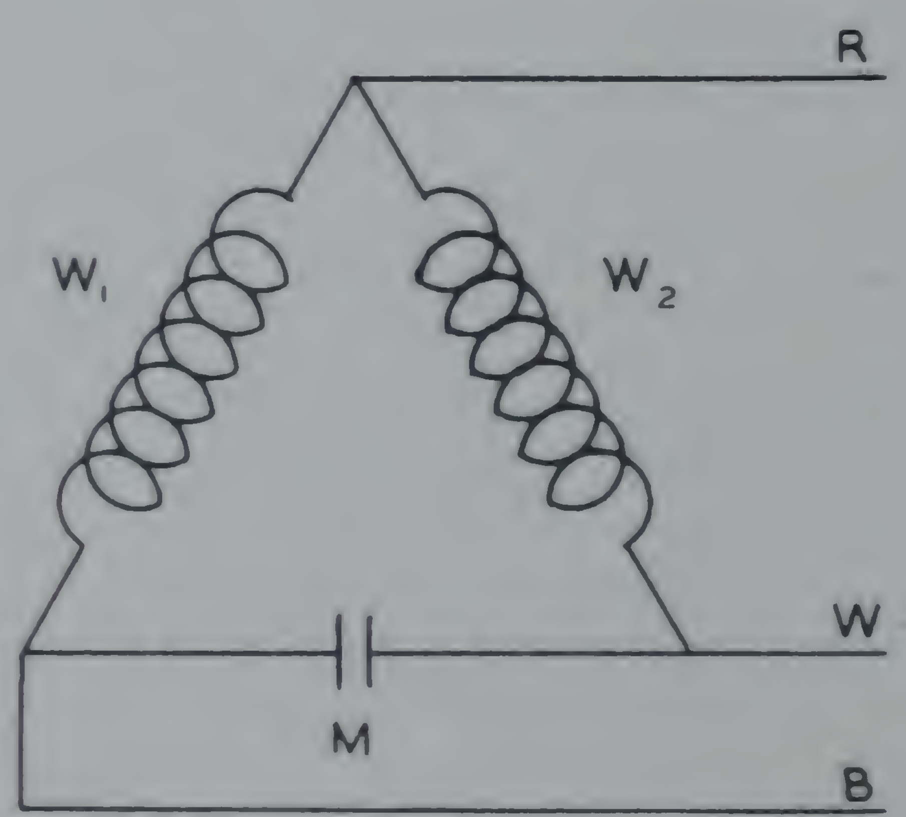

Figure 1

A schematic sketch of the power unit showing the coils and condenser together with their interconnections, is shown in Fig. 1. The red or common terminal, is connected to one side of the line. When power from the other side of the line is furnished to either the W or B terminal, the motor will operate. When power is furnished thru the W terminal, the motor runs in one direction and when power is furnished thru the B terminal, the motor runs in the opposite direction.

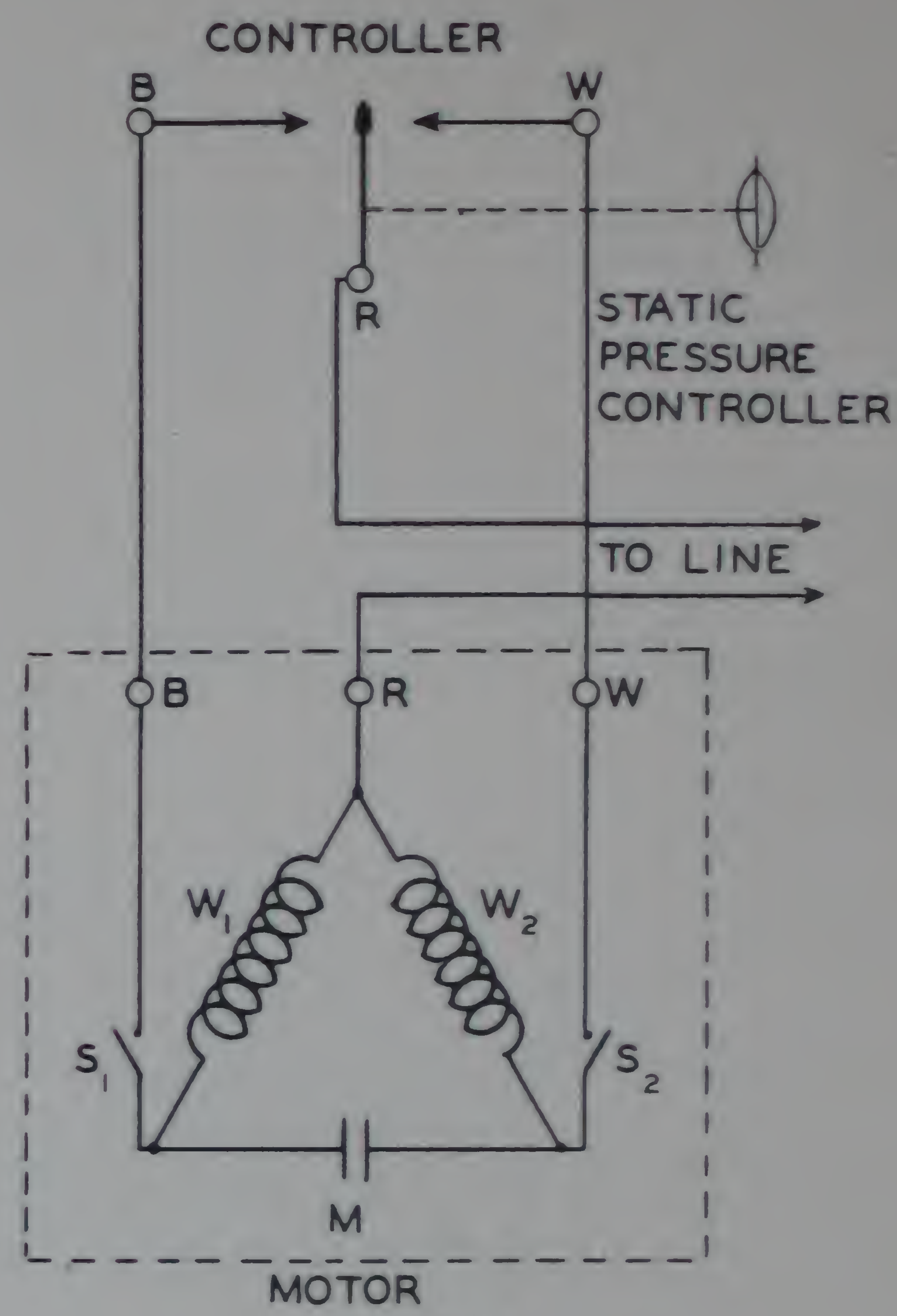

Figure 2

Figure 2 shows how the single pole double throw controller can furnish power to either the B or W terminal of the motor. If the controller is so positioned that the W terminal is energized, the current will flow directly through the W_2 winding, and will flow to the W_1 winding thru condenser M. This will cause the motor to revolve in one direction. If current is supplied to terminal B, winding W_1 will be energized directly, and winding W_2 will be energized through condenser M, which in turn will cause the motor to revolve in the opposite direction. When there is no power being furnished to either the white or the blue terminal, the motor will remain stationary.

Limit switches are included on floating motors so that the circuits from the white and from the blue terminals to the motor windings can be broken when the output shaft of the motor reaches a certain point in its rotation. In this way the stroke of the motor is limited to 160 angular degrees.

SERIES 60 FLOATING OPERATION

Fig. 2 illustrates a complete Series 60 floating control circuit. The equipment used includes:

1. **Static Pressure Regulator.**
2. **Series 60 Floating control motor.**

The static pressure regulator is so arranged that as the pressure rises the instrument will make its contact from red to white. As the pressure drops the instrument will close the circuit from red to blue.

The damper motor in this case will be arranged so that if power is applied to its red and blue terminals, the volume damper in front of the fan will open. In this way more air will be supplied to the fan and a higher pressure will be maintained in the discharge ducts.

When the equipment is connected together as illustrated in Fig. 2, the motor will remain at rest whenever the static pressure in the duct is the same as the setting of the static pressure regulator. As this pressure drops, the static pressure regulator will make its blue contact which will

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SERIES 60* FLOATING CONTROL CIRCUIT

start the motor operating in a direction to open the fan damper and thereby increase the pressure in the discharge duct. When the pressure has risen to the setting of the static pressure regulator again, the blue contact will be broken and the motor will stop.

If the pressure in the discharge duct, due to unusual conditions, does not rise far enough to break the blue contact, Limit Switch S_1 will break its contact when the motor has come to the end of its 160° stroke. This makes it impossible for damper linkages and dampers to become damaged as a result of the damper motor over traveling.

If the pressure in the supply duct rises above the setting of the static pressure regulator, the white contact of the regulator will be made. This will run the damper motor toward its closed position. When the static pressure in the duct drops again, the white contact will be broken and the motor will stop. Limit switch S_2 has the same action, of course, as Limit switch S_1 and will make it impossible for the motor to over travel on the closing stroke.

SERIES 90* CONTROL CIRCUIT

SERIES 90 APPLICATION

The Series 90 control circuit provides modulating, or proportioning, control action and may be applied to:

1. **Motorized Valves.**
2. **Motorized Dampers.**
3. **Sequence Switching Mechanisms.**

The Series 90 circuit operates to position the controlled device (usually a damper or motor valve) at any point between full open and full closed which will proportion the delivery to the need as indicated by the controller mechanism.

Modulating control is not subject to the operating limitations normally associated with two-position or floating control.

For example:

1. In two-position control a power unit, once energized, is limited in its operation by the action of the maintaining switch. It must run to one of its extreme positions and remain there until conditions at the controller have changed through the entire range of its differential.
2. In floating control a power unit, once energized, is limited in its operation by the length of time necessary to have the change in its position reflected at the controller location.
3. In modulating control a power unit, once energized, will run only enough to vary the supply in direct ratio to the amount of change in the controlled conditions. If a Series 90 thermostat having a 2 degree differential is used a change of 1/10° will cause the power unit to move 1/20 of its total travel. A change of 1/2° will cause a change in motor position of 1/4 of its total travel. Series 90 power units move a definite increment for every increment of change in controller position.

A complete Series 90 circuit may be obtained by combining any Series 90 controller with a motor power unit or relay constructed for proportioning action. Limit controls may be added where required and automatic compensation may also be provided.

SERIES 90 EQUIPMENT

Controllers

Series 90 controllers are constructed as:

1. **Room Thermostats**
2. **Insertion Thermostats**
3. **Humidity Controllers**
4. **Pressure Controllers**

Controllers for the Series 90 circuit vary from the contact types of mechanism in that the electrical mechanism consists of a variable potentiometer. These potentiometers include a contact finger which moves across a 135 ohm coil of resistance wire wrapped on a suitable bobbin. The contact finger is actuated by temperature, pressure, or humidity sensitive mechanisms.

Motors

A Series 90 motor consists of the following:

1. **Reversible capacitor type power unit.**
2. **Balancing Relay.**
3. **Balancing Potentiometer.**

The power unit is a low voltage capacitor type motor which drives the output shaft of the motor thru a speed reducing gear train. Limit switches are operated by the shaft so that its rotation is limited to 160 degrees. The gear train and all other moving parts are oil immersed to eliminate the necessity for periodic lubrication, and to insure long quiet service.

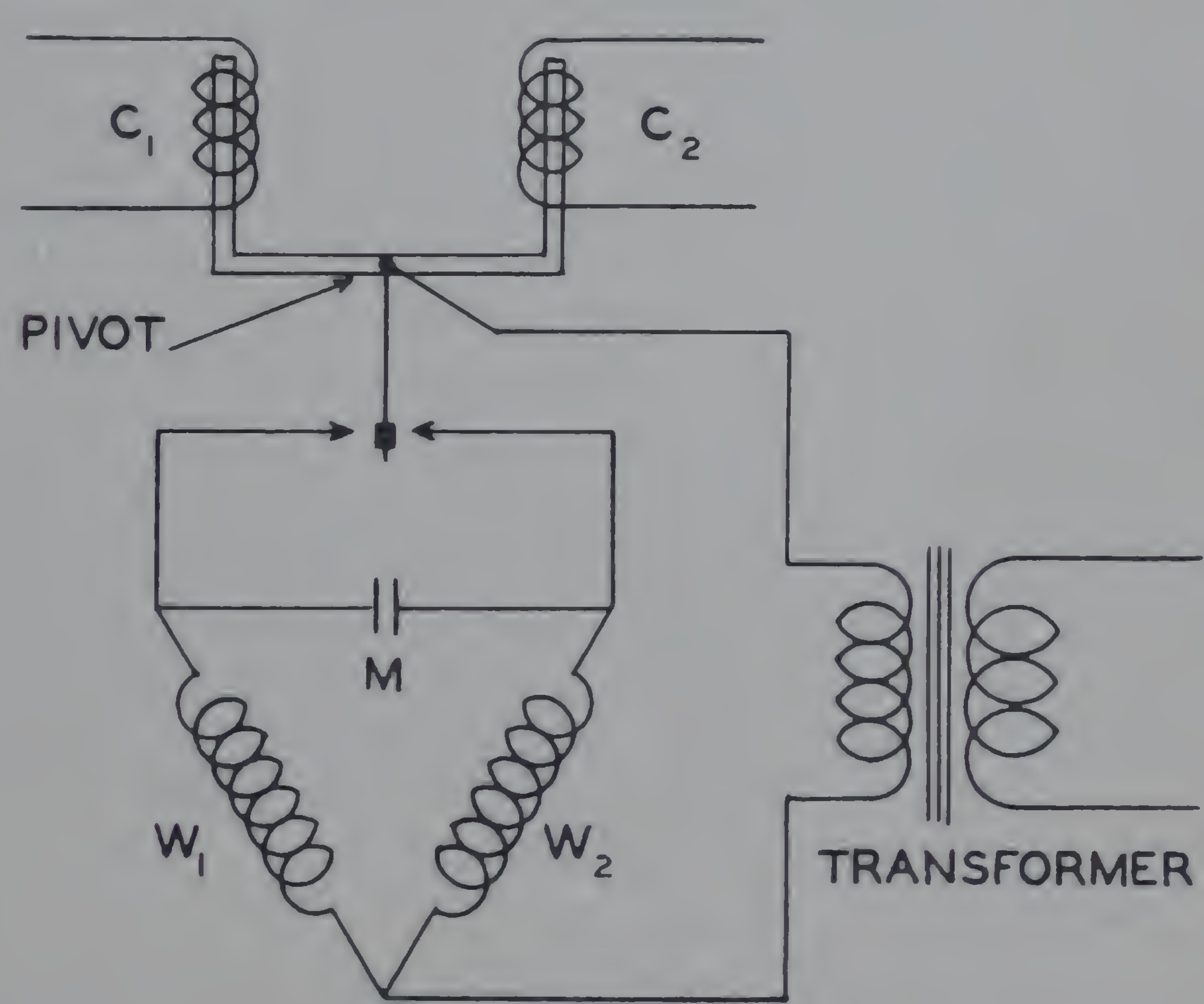

Figure 1

The power unit is started, stopped and reversed by the single pole double throw contacts of the balancing relay (See Fig. 1). The balancing relay consists of two solenoid coils with parallel axes, and a U-shaped armature. The armature is pivoted in the center and each leg extends into the hollow core of one of the solenoid coils.

A contact arm is fastened to the armature so that one or the other of two stationary contacts can be made as the armature is moved back and forth on its pivot by the action of the relay coils. When the relay is in a balanced condition, the contact arm floats between the two stationary contacts.

*Trade Mark

SERIES 90* CONTROL CIRCUIT

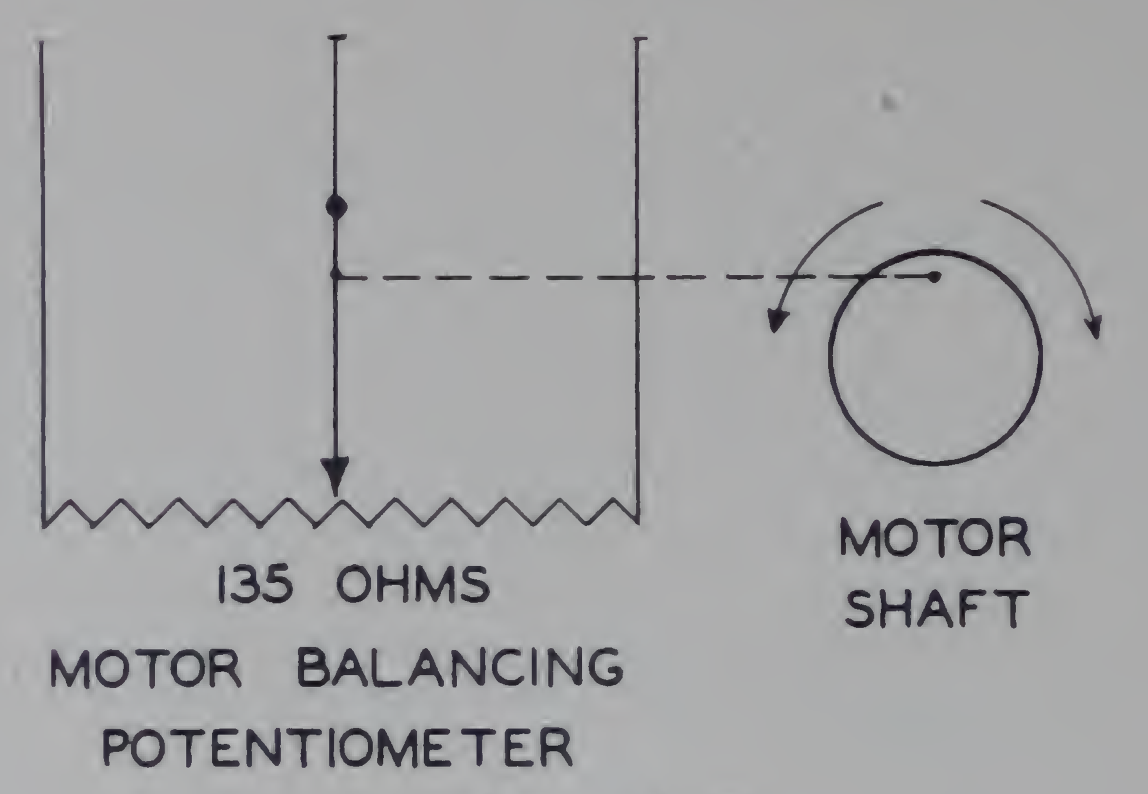

Figure 2

A balancing potentiometer is also included within the housing of a modulating Series 90 motor. This potentiometer is electrically identical with the one in the series 90 controller. It consists of a 135 ohm coil of wire wound on a bobbin. A contact finger operated from the shaft of the motor wipes the potentiometer coil (See Fig. 2).

SERIES 90 OPERATION

Balancing Relay

Figure 1 illustrates the function of the balancing relay in the Series 90 circuit. When the same amount of current is flowing through both coils of the relay, the contact blade will be in the center of the space between the two contacts and the motor will be at rest.

Changes in the conditions at the controller (controller not shown in this sketch) will affect the circuit so that the amount of current flowing through the two relay coils will not be identical. Whenever the current through these two coils becomes unbalanced, one of them will become stronger and the U-shaped armature will be moved. The movement of the armature will close one of the relay contacts which in turn will start the motor running in the proper direction.

If coil C_1 becomes the stronger, the contact blade will be moved toward the left, making a circuit from one side of the transformer directly to motor winding W_1. Current will also be furnished to motor winding W_2 thru the condenser M. The motor will then operate in one direction until the contact at the balancing relay has been broken.

Likewise if coil C_2 becomes the stronger of the two coils, the right hand contact will be made and winding W_2 will be powered directly while winding W_1 of the motor is powered through condenser M. This will cause the motor to revolve in the opposite direction.

Motor Balancing Potentiometer

The motor shaft is linked to the potentiometer wiper in such a manner that there is a definite wiper position for each position which the motor shaft may take up within its 160° arc. For example when the motor crank arm is 25% or 40 rotational degrees from one of its extremes, the potentiometer wiper will be at a point 25% or 34 ohms from its corresponding extreme.

Control Circuit

Figures 3, 4, and 5 show schematically the complete circuit as used with Series 90 equipment.

Consider an instantaneous condition when the current is flowing from the transformer to the wiper blade of the thermostat as indicated by the arrows in the sketches. In Figure 3, when the current reaches the potentiometer winding of the controller, it will be split evenly so that half the current flows down the right leg of the circuit, thru R_2, thru balancing coil C_2, thru part of the balancing potentiometer on the motor R_4, and back to the other terminal of the transformer. Likewise, the other half of the current will flow down the left leg of the circuit, thru R_1 of the thermostat potentiometer, thru balancing relay coil C_1, thru R_3 of the motor balancing potentiometer, and thence back to the transformer.

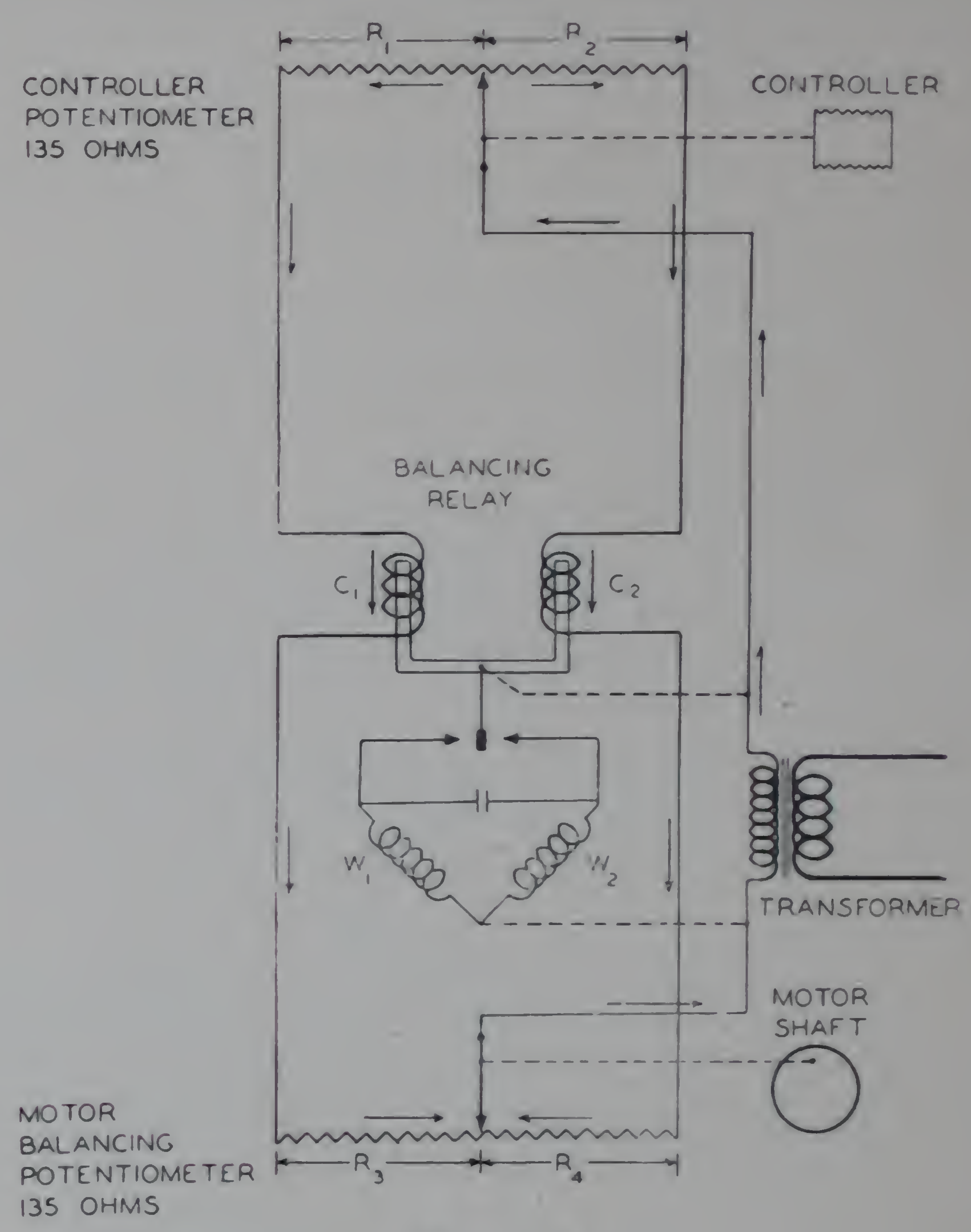

Figure 3

Figure 3 shows an entirely static condition of the system. Equal amounts of current are flowing down both sides of the circuit because the total resistance in each leg is equal. Therefore the balancing relay contact arm is floating between its two contacts. Since no power is being furnished to either winding of the motor the circuit to the motor windings is shown dotted. The motor will be at rest.

Figure 4 shows a condition where the temperature has changed and as a result the wiper arm of the thermostat has travelled toward the right hand extreme of its potentiometer winding. The amount of resistance to either side of the thermostat wiper is no longer equal. R_1 on the left side of the potentiometer winding is greater than R_2 which represents the right hand portion of the coil.

Again consider an instantaneous condition just after the wiper of the thermostat has moved to this new location toward the right end of its potentiometer. The resistance path on the right hand side of the circuit is considerably less than the resistance path on the left hand side. It follows then that more current will flow down the right leg of the circuit because the current will follow the path of least resistance. This is indicated by the heavy arrows representing the current in the right leg of the circuit as opposed to the dotted arrows representing the current in the left leg.

*Trade Mark

SERIES 90* CONTROL CIRCUIT

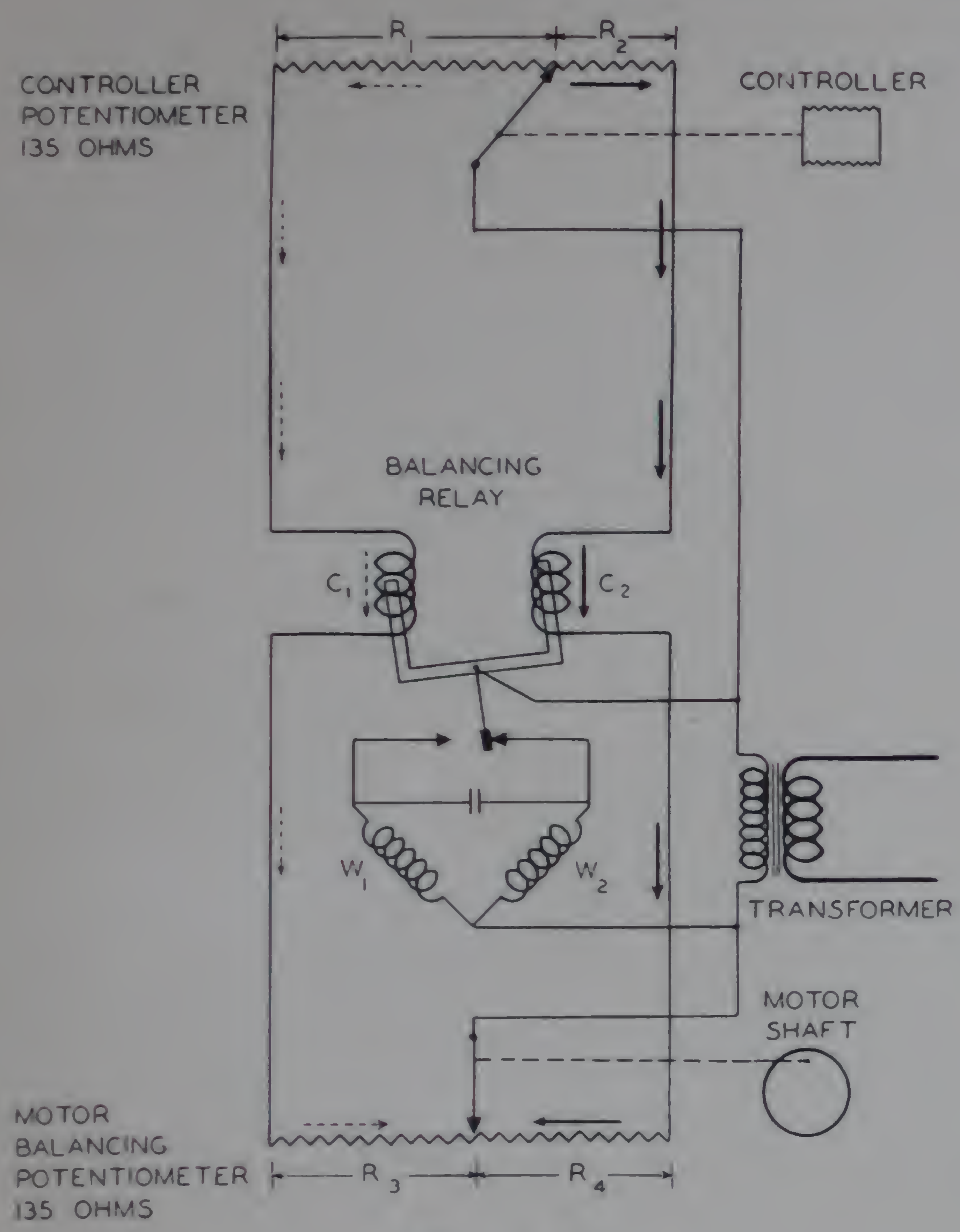

Figure 4

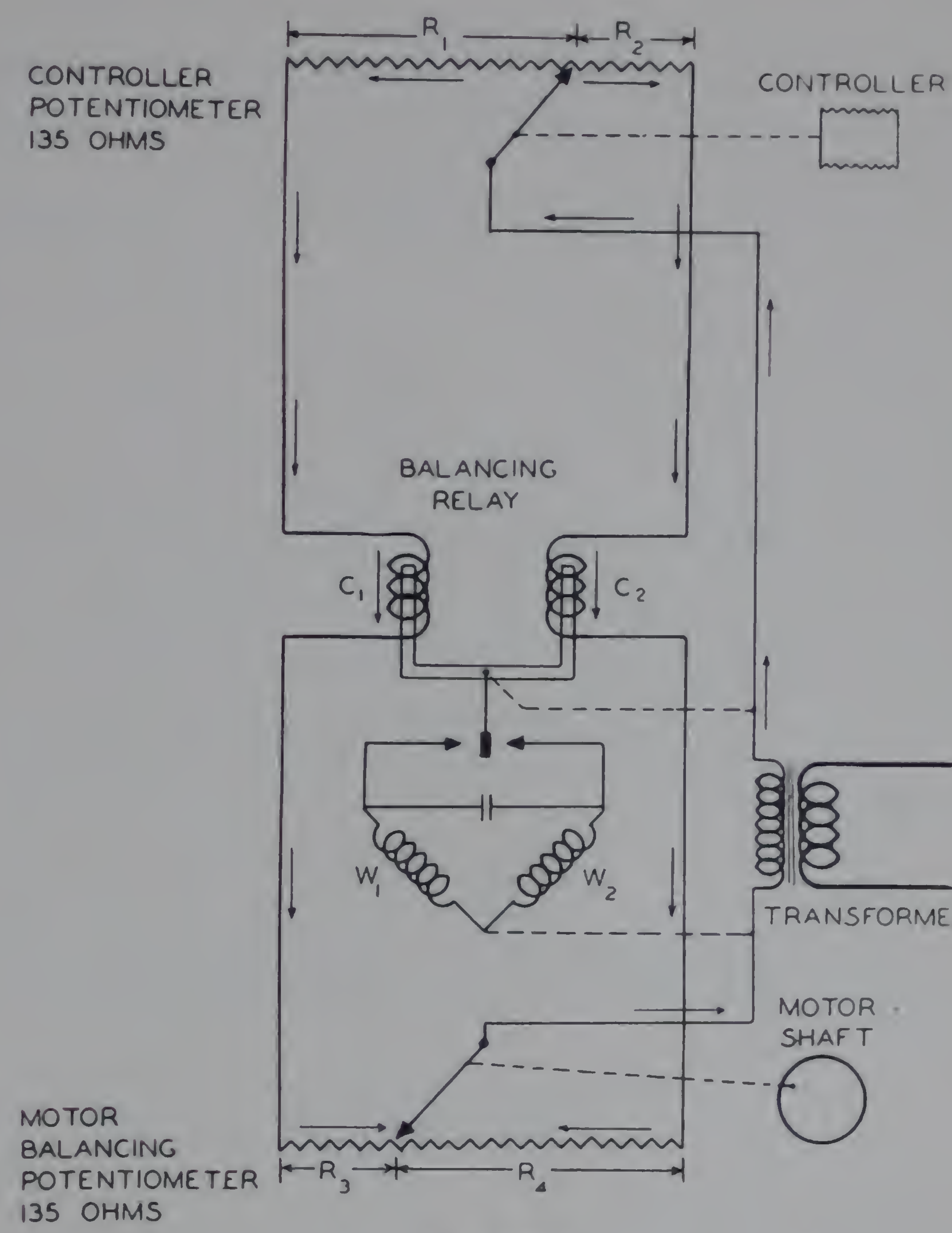

Figure 5

Since there is more current now flowing thru balancing relay coil C_2, this coil will over-balance the pull of relay coil C_1 and a circuit thru the right hand contact of the balancing relay will be made. Current will now be fed directly to motor winding W_2 and will cause the motor to run in the corresponding direction. The wiper of the motor balancing potentiometer as indicated in the sketches is linked directly to the shaft of the motor. As the motor shaft starts to rotate, it moves the wiper arm of the balancing potentiometer to a new position.

Figure No. 5 shows another instantaneous condition of the system after the motor shaft has moved the balancing potentiometer wiper to a position which is identical with the position of the potentiometer wiper in the thermostat. At this condition the right hand side of the balancing potentiometer will have a resistance value identical with the left hand side of the thermostat potentiometer, which means R_1 equals R_4. Likewise R_3 of the motor balancing potentiometer will equal R_2 of the thermostat potentiometer. When this condition has been reached, the current flowing thru both legs of the circuit will be identical and therefore the balancing relay coils C_1 and C_2 will have an equal effect on the armature. The armature will then cease to make contact and the motor will again come to rest.

By careful analysis of these diagrams, it can be seen that the motor will run until the wiper of its balancing potentiometer has reached a point on the winding which is identical with the position of the control wiper blade. As soon as this point is reached, the balancing relay coils will balance out and the motor will come to rest.

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M-H Control Combinations

The preceding sections have described and illustrated the purpose and operation of the various basic control circuits.

In actual application these basic control arrangements are frequently expanded to make provision for added refinement, such as:

1. **High limit protection.**
2. **Low limit protection.**
3. **Compensated Control.**
4. **Positive cycling sequence.**

When extra control units are provided for these purposes it becomes necessary to consider the manner in which they should be connected into the basic circuit.

A few of the more common applications have been selected and the electrical interrelationship between primary and limiting control units for these are discussed in the following paragraphs.

It should be remembered that in all of these applications the basic control circuit operation remains unchanged.

SERIES 10

The accompanying connection diagrams illustrate the manner in which various Series 10 controllers and relays or other Series 10 devices may be wired together to obtain a given result.

HIGH LIMIT CONTROL

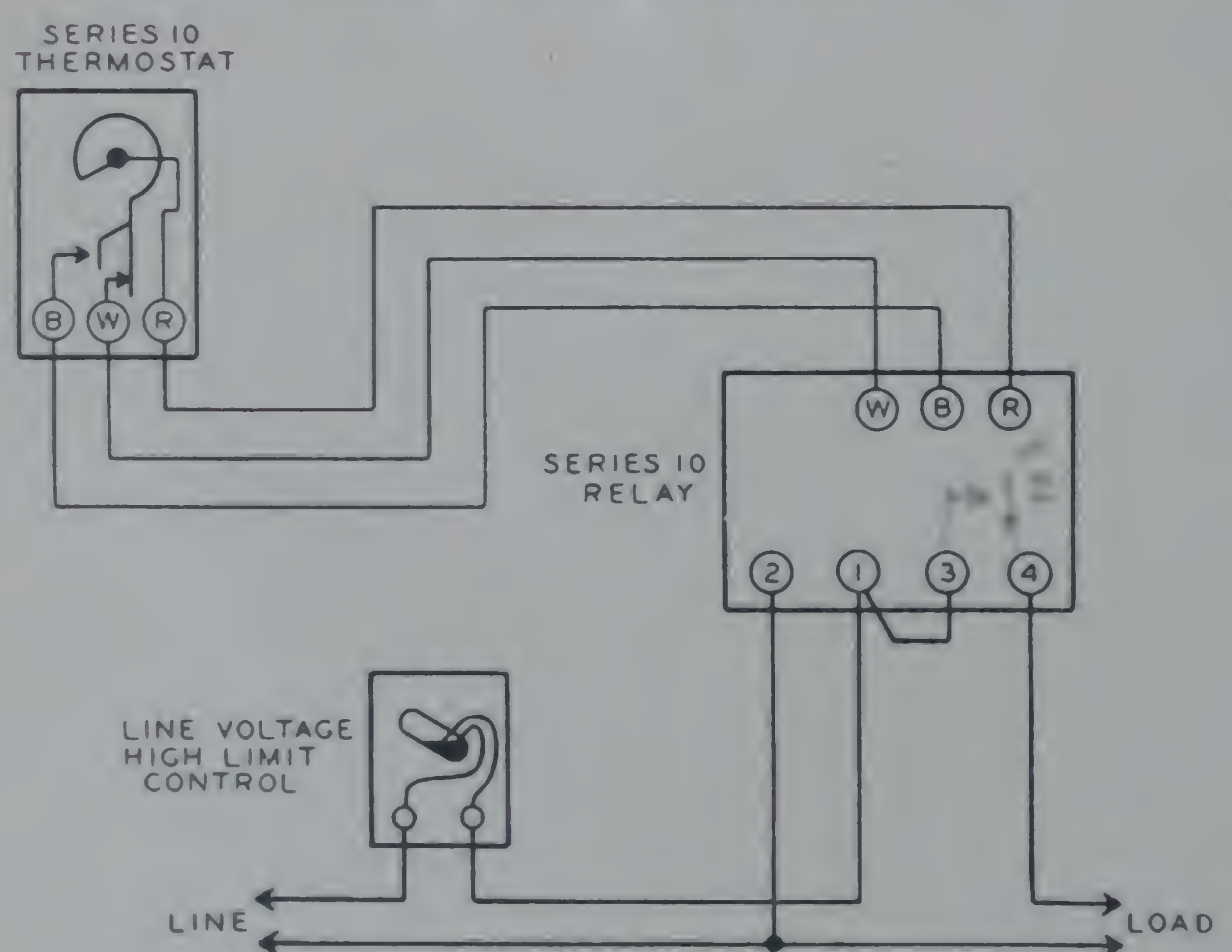


Figure 1

Figure 1 shows a typical Series 10 circuit similar to that described on page 49 to which has been added a "high limit" control. The relay may be used to start and stop an automatic oil burner or stoker on a residential heating system at the command of the thermostat located in one of the rooms. The high limit control serves to prevent execessive temperatures in the furnace or boiler.

It can be seen that the Series 10 relay pulls in whenever the thermostat contacts "W" and "B" are closed. The holding circuit is completed which will maintain the relay energized through "R" and "W." If the thermostat is satisfied, the "W" contact breaks, dropping out the relay.

With the relay energized, it can be seen that whenever a high limit condition exists, such as temperatures or pressures above the desired point, a mercury switch control interrupting the power supply to the relay will cause the relay to drop out and the circuit to the automatic fuel burner will thereby be interrupted.

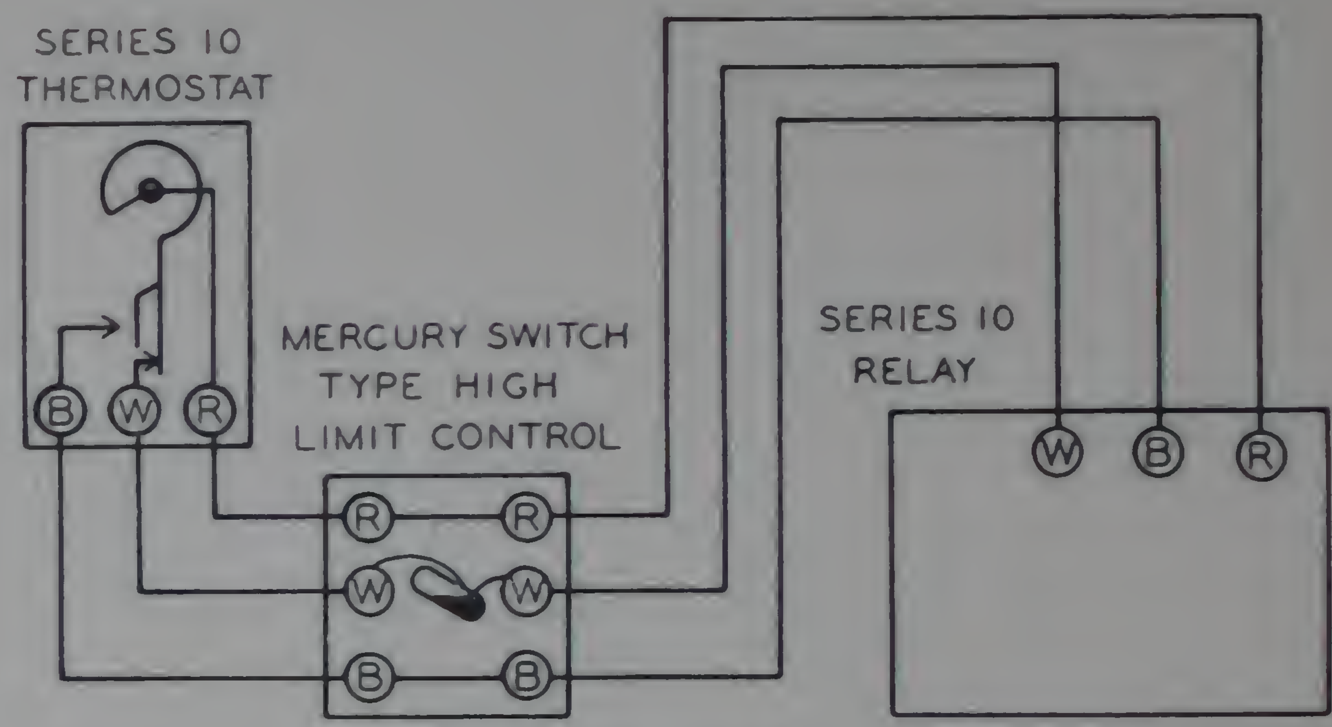


Figure 2

Fig. 2 is similar to Fig. 1 with the exception that the high limit control is located in the low voltage control circuit. The differential is obtained in the mercury switch because its inherent construction requires a change in temperature of several degrees before the bi-metal sensitive element will tip it from the "on" to the "off" position or vice versa. It is therefore necessary to break only the white wire circuit to prevent the thermostat from operating the burner. It will be noted that although the limit control is equipped with two sets of red, white and blue terminals to simplify the wiring, the mercury switch breaks only the white wire. Jumpers are connected internally in the blue and red wires.

LOW LIMIT CONTROL

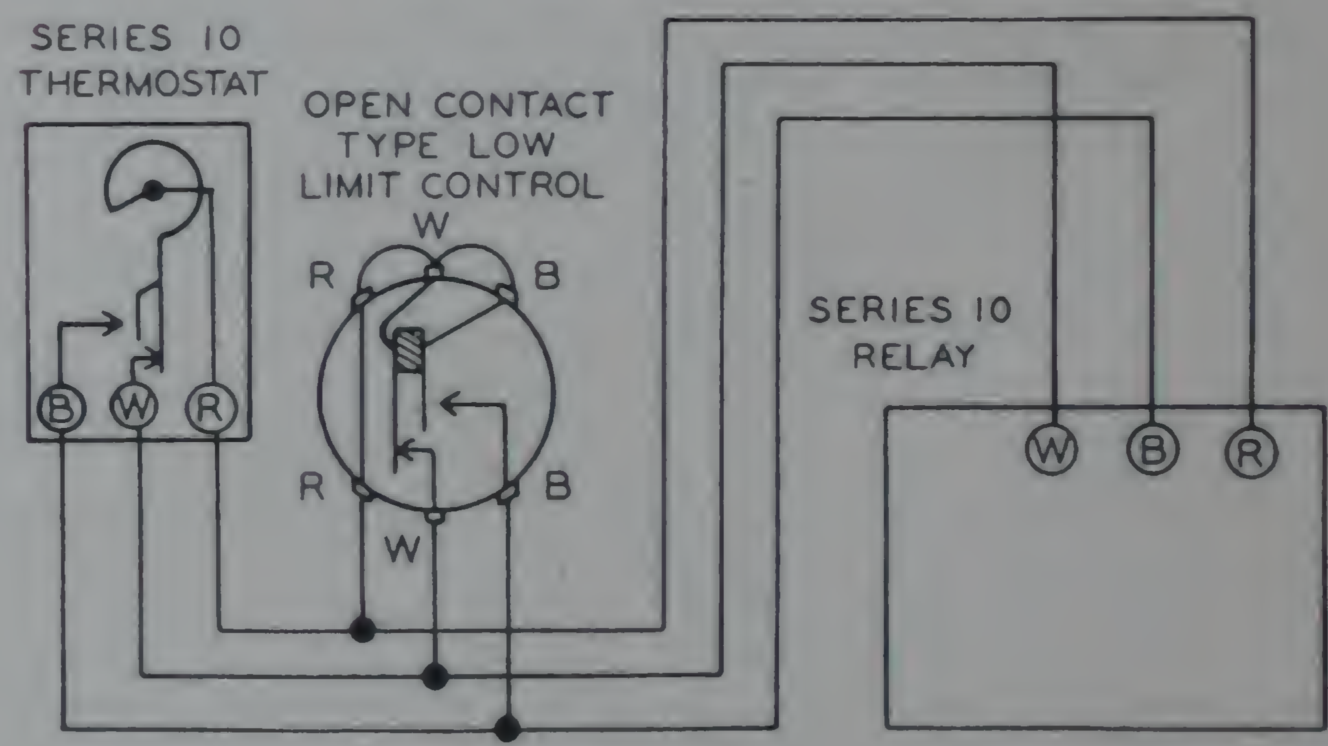


Figure 3

Fig. 3 illustrates the use of an open contact type limit control in the circuit so that it will operate as a low limit. It then operates to start the burner or stoker independently of the room thermostat, whenever the temperature drops below the point for which the low limit is set, however, both controls must be satisfied before the burner will stop. Note that when a jumper is placed across the upper red, white and blue terminals of the limit control as in Fig. 3, the control becomes similar in its internal wiring, to a room thermostat, with the two blades electrically connected together with the lower red terminal. It could, therefore, operate the relay without the use of a thermostat, and is very often used for that purpose. The control circuits of Figs. 1 and 3 are often combined to satisfactorily control a heating plant. A high limit control is used to prevent excessive water or furnace temperatures, while the low limit is used to maintain the proper temperature of water in hot water supply tank. The circuit shown in Fig. 1 is then used, with the low limit control wired in parallel with it (color to color) between the room thermostat and high limit control.

M-H CONTROL COMBINATIONS

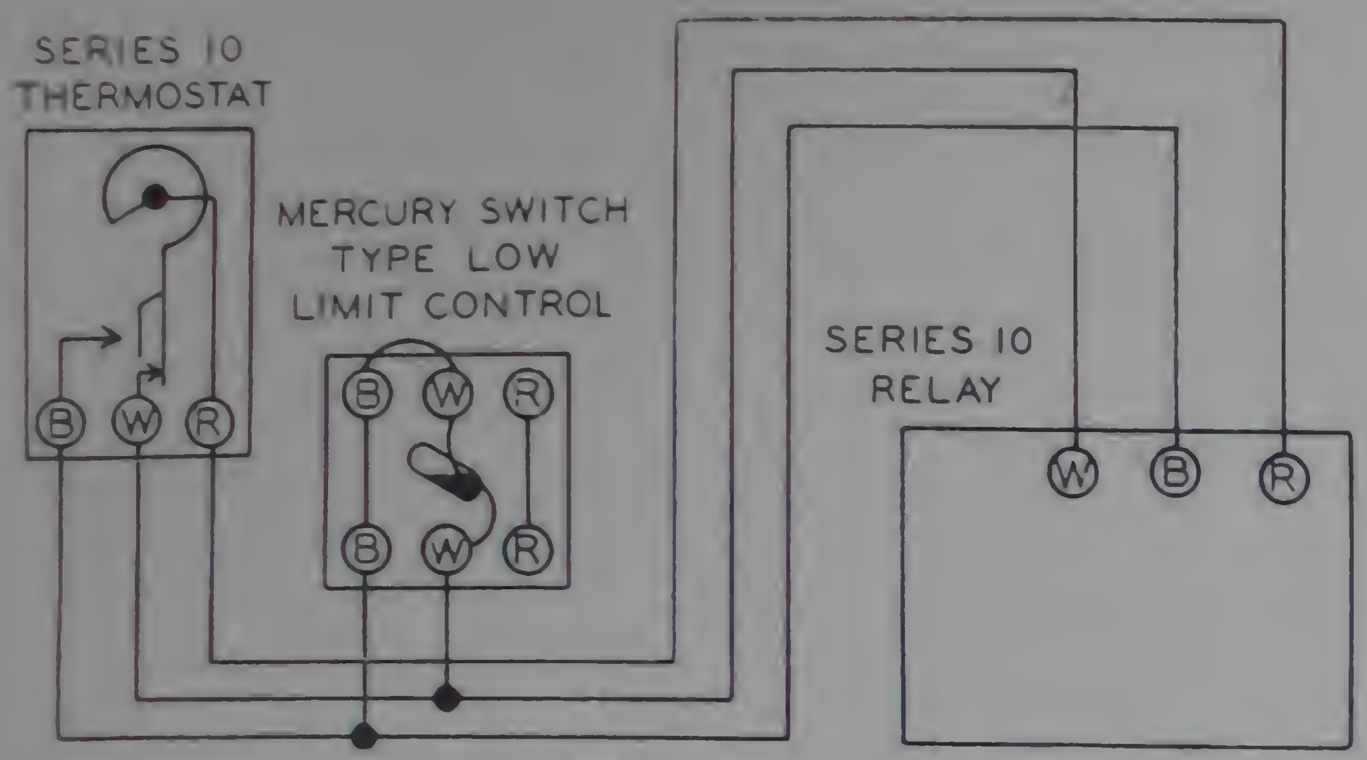


Figure 4

Fig. 4 illustrates how a mercury switch control may be connected to operate as a low limit. Note that only the blue and white terminals are used.

HIGH AND LOW LIMIT CONTROL

A Series 10 relay or valve may be operated by a two-wire thermostat or controller, either alone or in conjunction with other two-wire thermostats or controllers. In all cases, however, the controller must be of the mercury switch type or one equipped with contacts that "snap" open or closed by means of a magnetic or spring action.

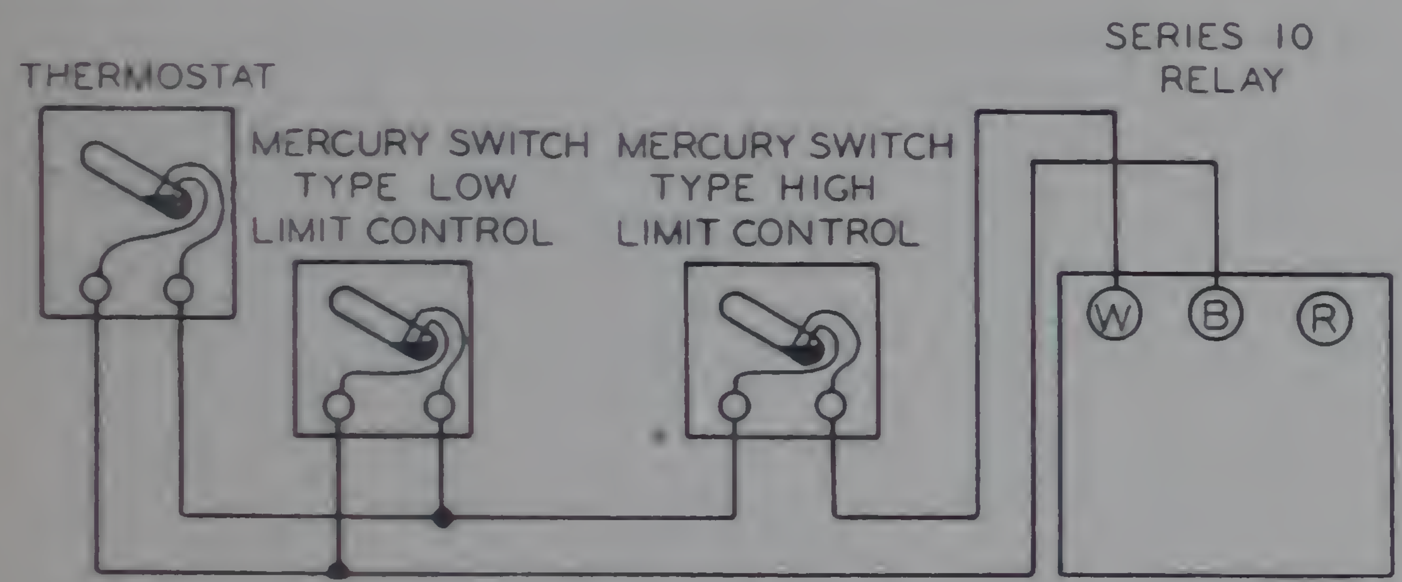


Figure 5

Fig. 5 indicates the method of connecting up a room thermostat, low limit and high limit, all of the two-wire type, to operate a Series 10 device.

SERIES 20

Figures 1 to 4 show various combinations of Series 20 controllers and limit controls. The construction and operation of Series 20 and Series 10 open contact type limit controls are identical except that the stationary contacts of the Series 20 control are placed on either side of the movable blades.

HIGH LIMIT CONTROL

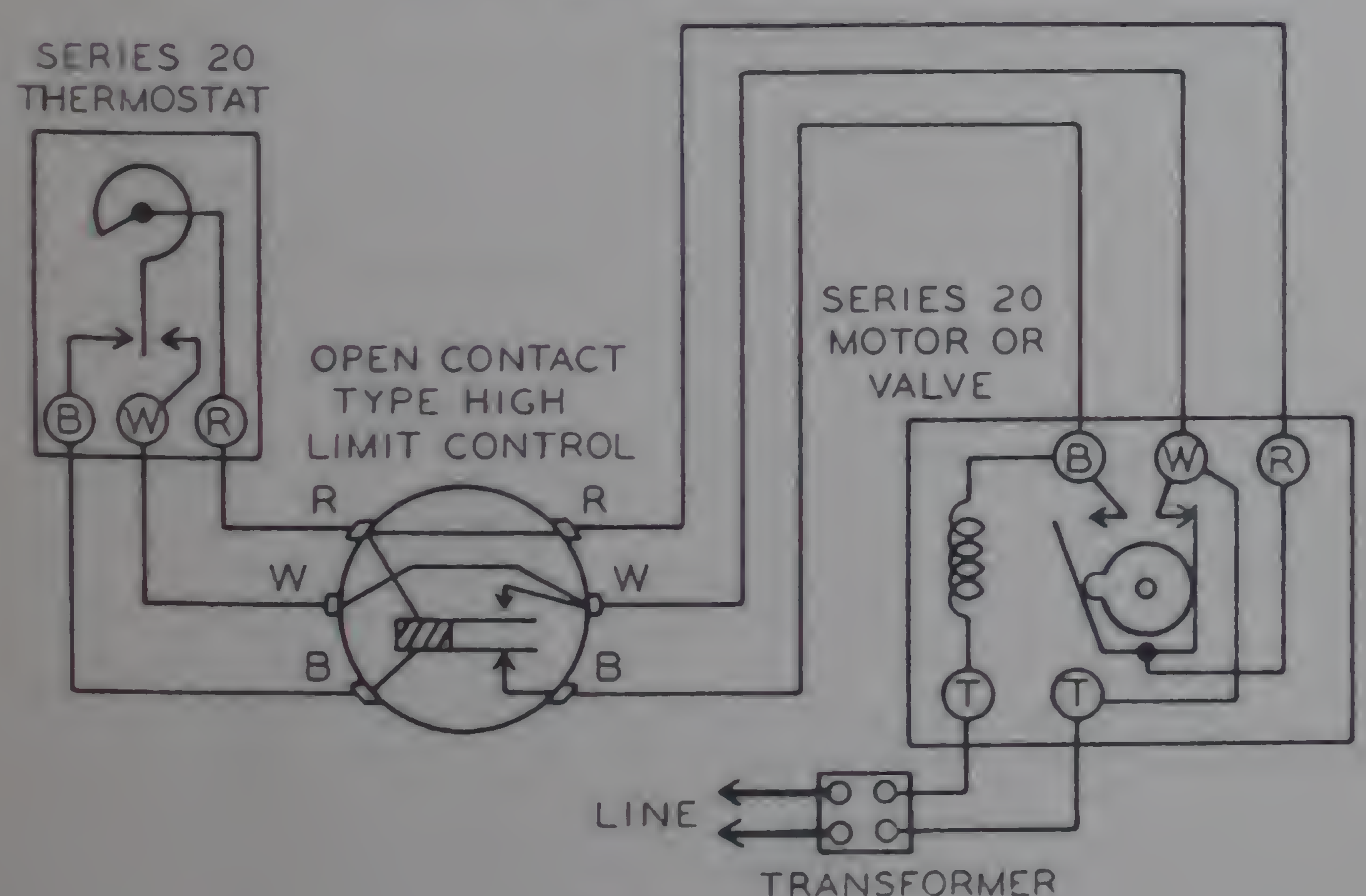


Figure 1

Referring to Fig. 1, when the temperature at the limit control is below the setting, the circuit between the two blue terminals of the limit control is completed. It will be noted, then, that the connections between the thermostat and motor run straight through, just as they would if the limit control were entirely removed from the circuit. Thus, the thermostat is placed in complete command of the motor.

If the temperature of the medium actuating the limit control should be increased an amount equal to the differential, above the temperature at which the blue contacts were closed, the blue circuit would be opened and a "short" placed between the red and white circuits. The high limit control, therefore, definitely drives the motor to the closed position, even though the thermostat may be calling for heat, since the opening circuit (blue circuit) is broken in the limit control.

This combination of controls is commonly used with hand-fired heating plants, in which case the thermostat and motor act to control the opening and closing of the draft and check dampers. The high limit control is placed in the furnace bonnet or boiler and operates to close the draft damper whenever the bonnet or water temperature exceeds a predetermined high limit.

LOW LIMIT CONTROL

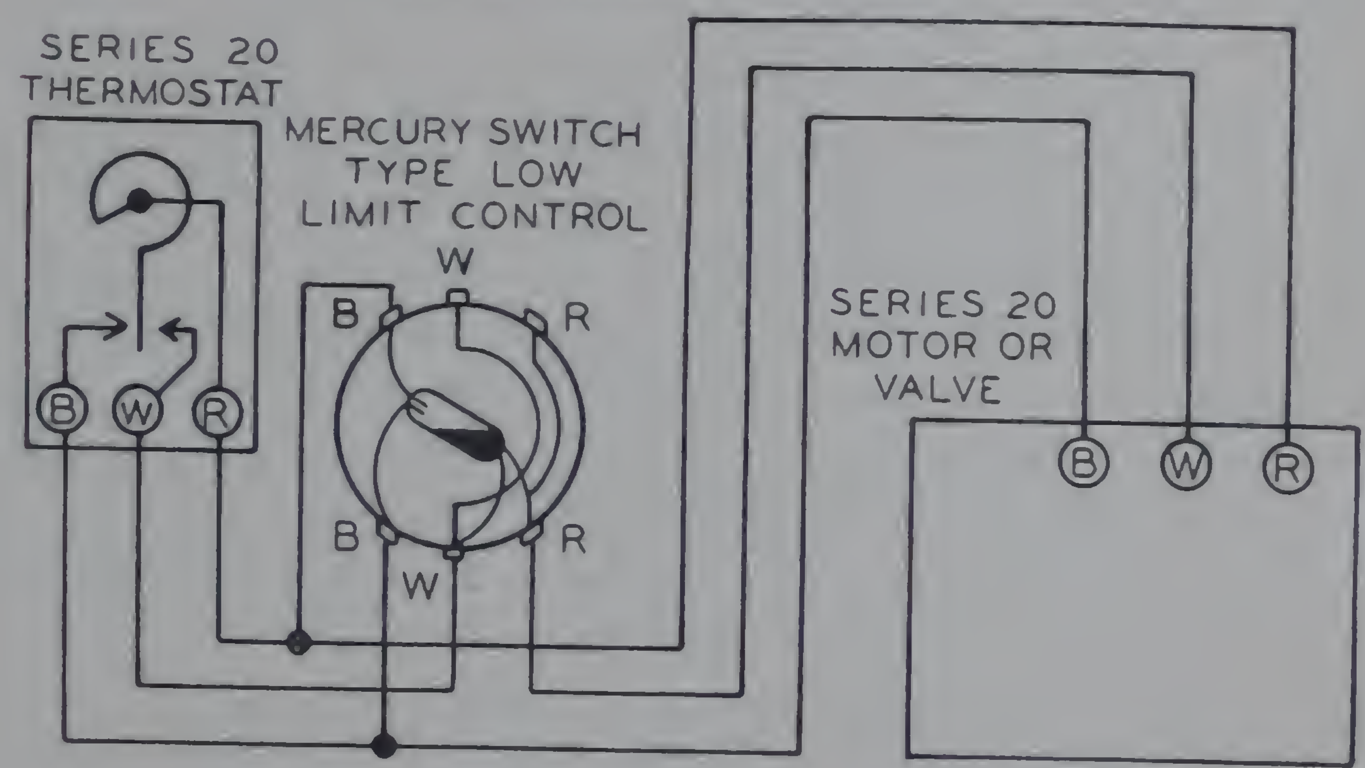


Figure 2

In Fig. 2 the limit control is connected as a low limit and will operate the motor to the open position when subjected to a temperature below that for which it is set, even though the thermostat may be calling for the motor to go to the closed position. The low limit control may then operate similarly to the Series 10 low limit previously described, to maintain the required temperature in a hot water supply tank. The limit control in Fig. 2 is of the mercury tube type; however, it will be noted that the switching action is identical to that of the open contact type. Both types are in common use for the same purpose.

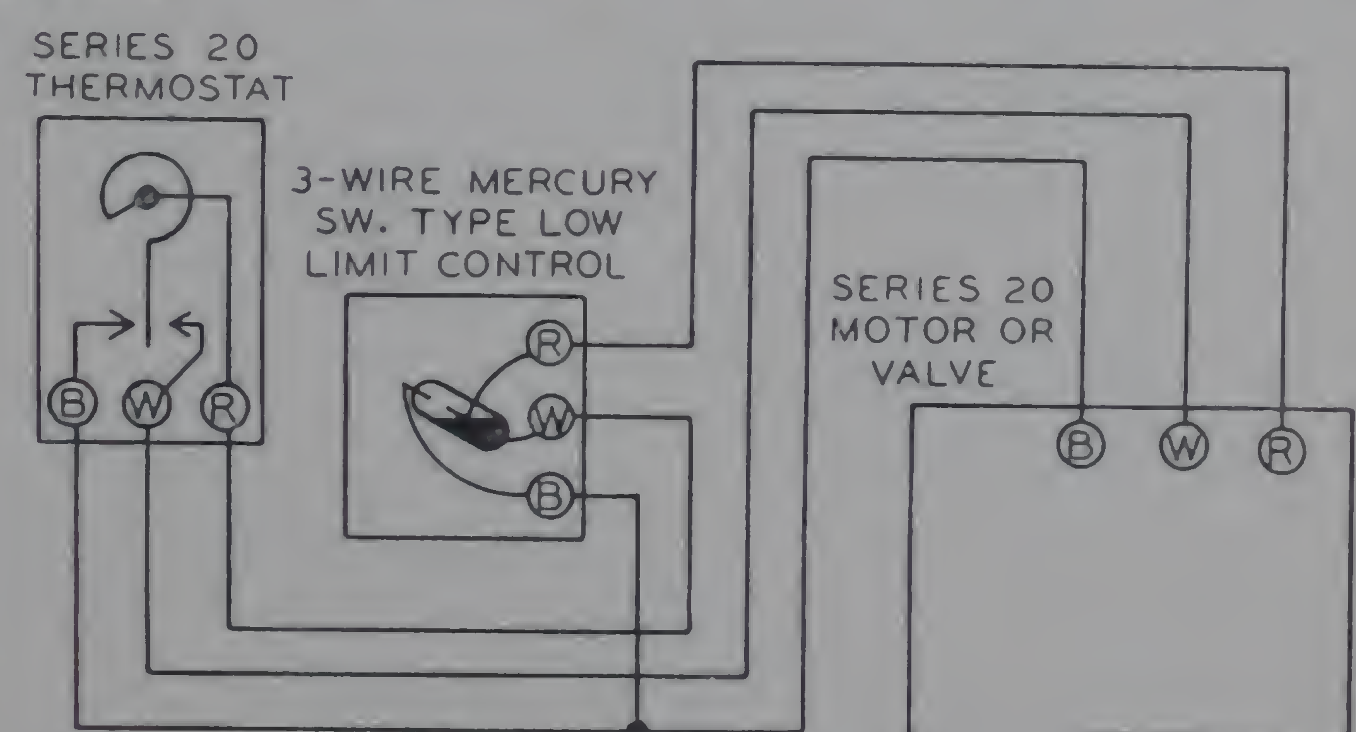


Figure 3

A three-wire mercury tube type low limit control is shown in Fig. 3 in conjunction with the Series 20 ther-

M-H CONTROL COMBINATIONS

mostat and motor. The 3-wire tube is commonly used in vapor-tension operated controllers, both in the room type as well as the remote bulb type. The function of the limit control in this circuit is similar to that of the one in Fig. 2. The switching action, however, is slightly different in that when the limit control closes the blue circuit to the motor on a demand for heat, it breaks the red instead of the white circuit to the thermostat.

MANUAL SWITCH CONTROL

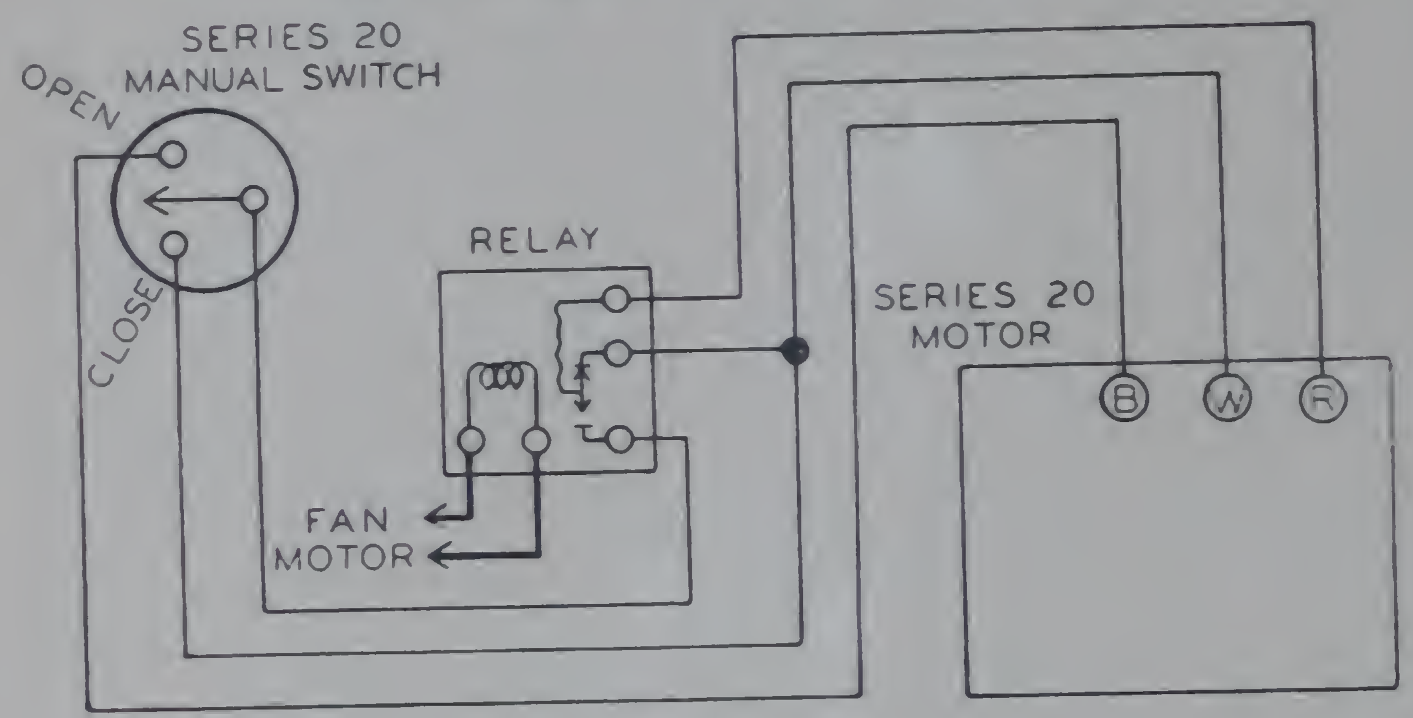


Figure 4

In Fig. 4 a relay with a Series 20 switching action is shown operating in conjunction with a manually operated Series 20 switch. This combination of controls might be used in connection with a fan ventilating system, for controlling the vent damper. In this system the relay coil is connected to the motor side of the fan starting switch, so that the "common" and "in" contacts of the relay will be closed when the fan is running. In this position, the relay places the manual switch in control of the vent damper motor. If, however, the ventilating fan is shut down, and the operator neglects closing the damper by means of the manual control, the relay, in dropping out will automatically close it and thereby prevent outdoor air from entering the building through the ventilating shaft.

SERIES 30

The method of wiring a limit control into the circuit of a Series 20 controller and Series 30 relay is shown in Fig. 1.

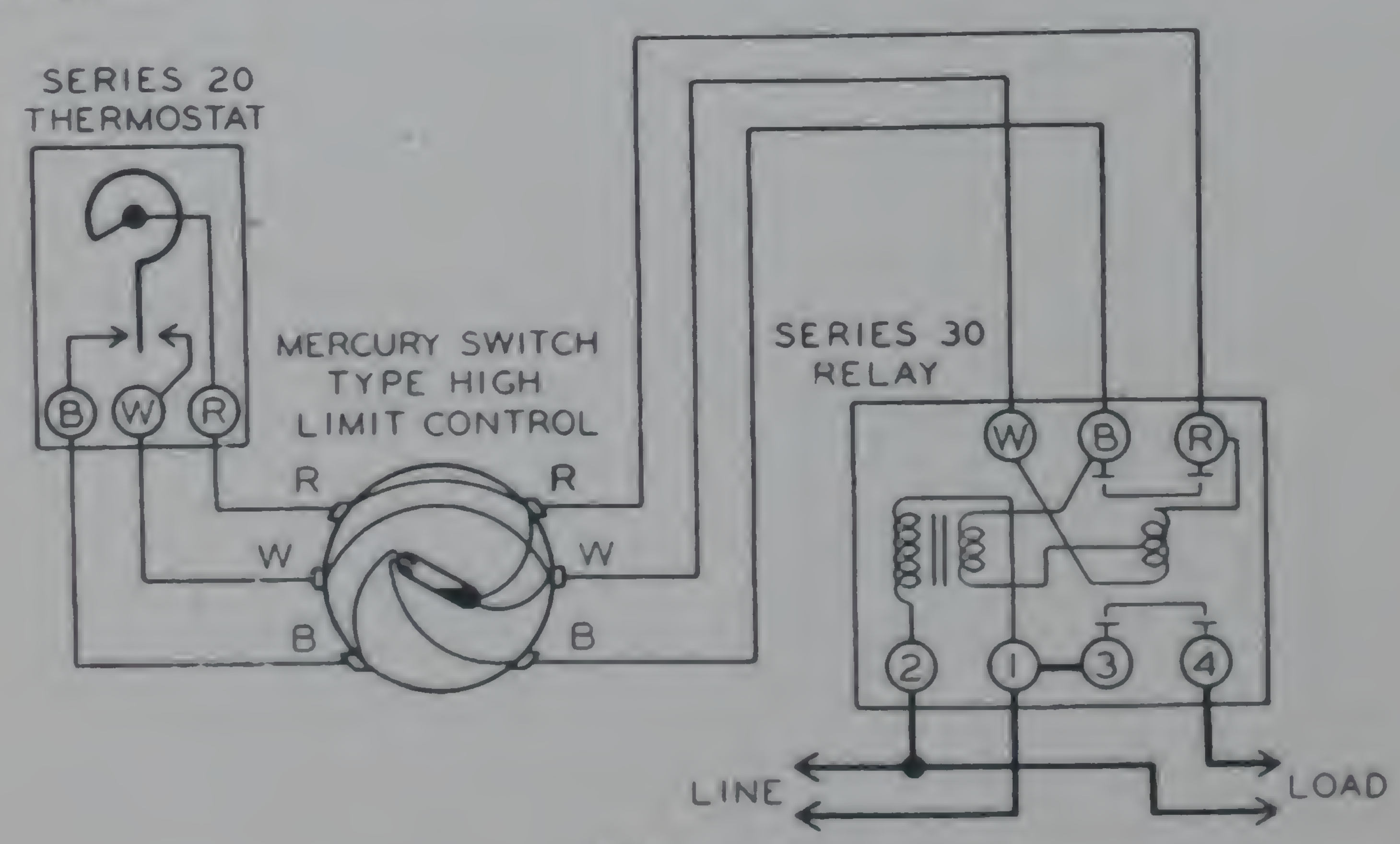


Figure 1

It will be noted that a standard Series 20 limit control is used for this purpose and that the connections between all terminals are identical with those of the Series 20 circuits.

SERIES 40 AND 80

UNIT HEATER CONTROL

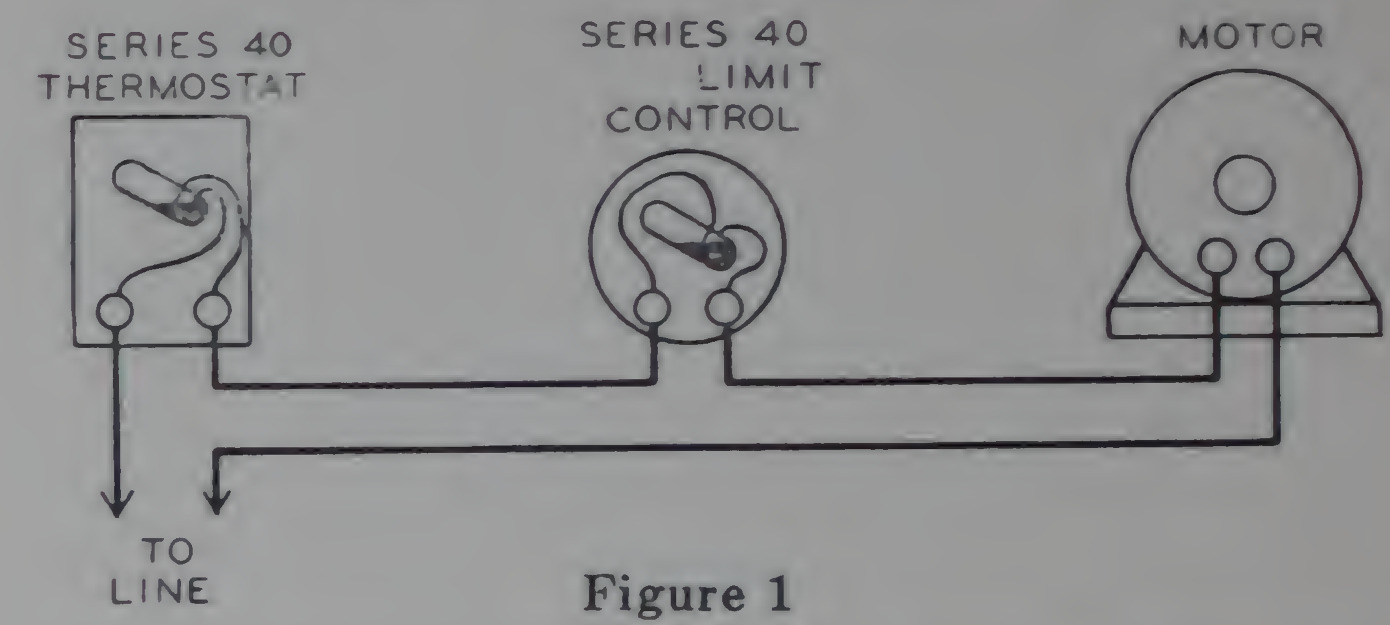


Figure 1

Fig. 1 illustrates a typical Series 40 control circuit which might be used where it is desired to control a unit heater from a room thermostat. It is usually necessary to provide some means of preventing the heater fan from running unless heat is being supplied to the heater coils in order to avoid uncomfortable drafts which might result from the circulation of unheated air. This may be accomplished by mounting a pressure control in the steam supply to the unit heater and connecting it in series with the thermostat and motor as shown in Fig. 1. The pressure control should be of the reverse acting type.

SOLENOID VALVE CONTROL

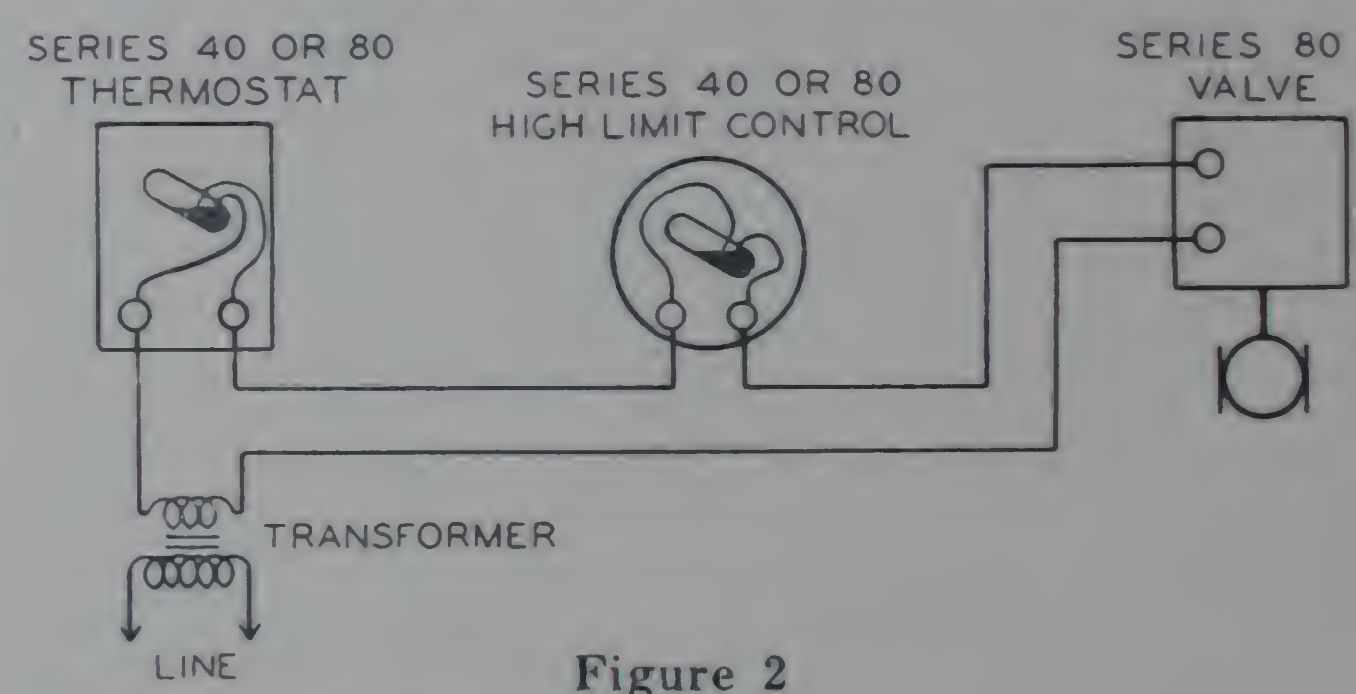


Figure 2

The circuit shown in Fig. 2 is that of a two-wire controller and limit control operating a Series 80 solenoid valve. Note that the two circuits are identical except that in the Series 80 circuit the power supply is obtained through a transformer. In either the Series 80 or Series 40 control systems the controls must be equipped with snap acting or mercury tube contacts in order to prevent supersensitive operation or short cycling.

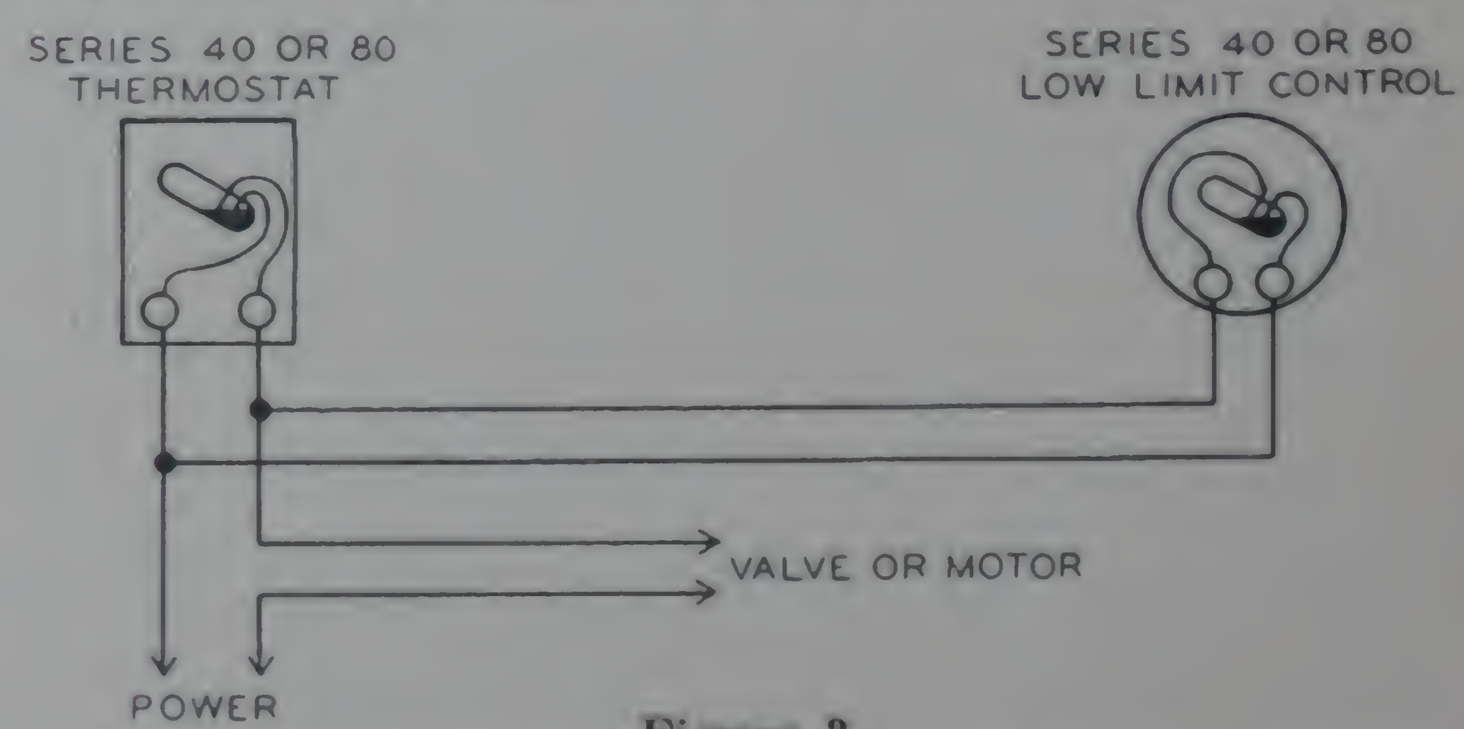


Figure 3

Low limit controls in either Series 40 or Series 80 control circuits are connected in parallel with the controller as shown on Fig. 3. With this type of connection the low limit controller can complete the circuit through the valve even though primary control unit is in the "off" position.

M-H CONTROL COMBINATIONS

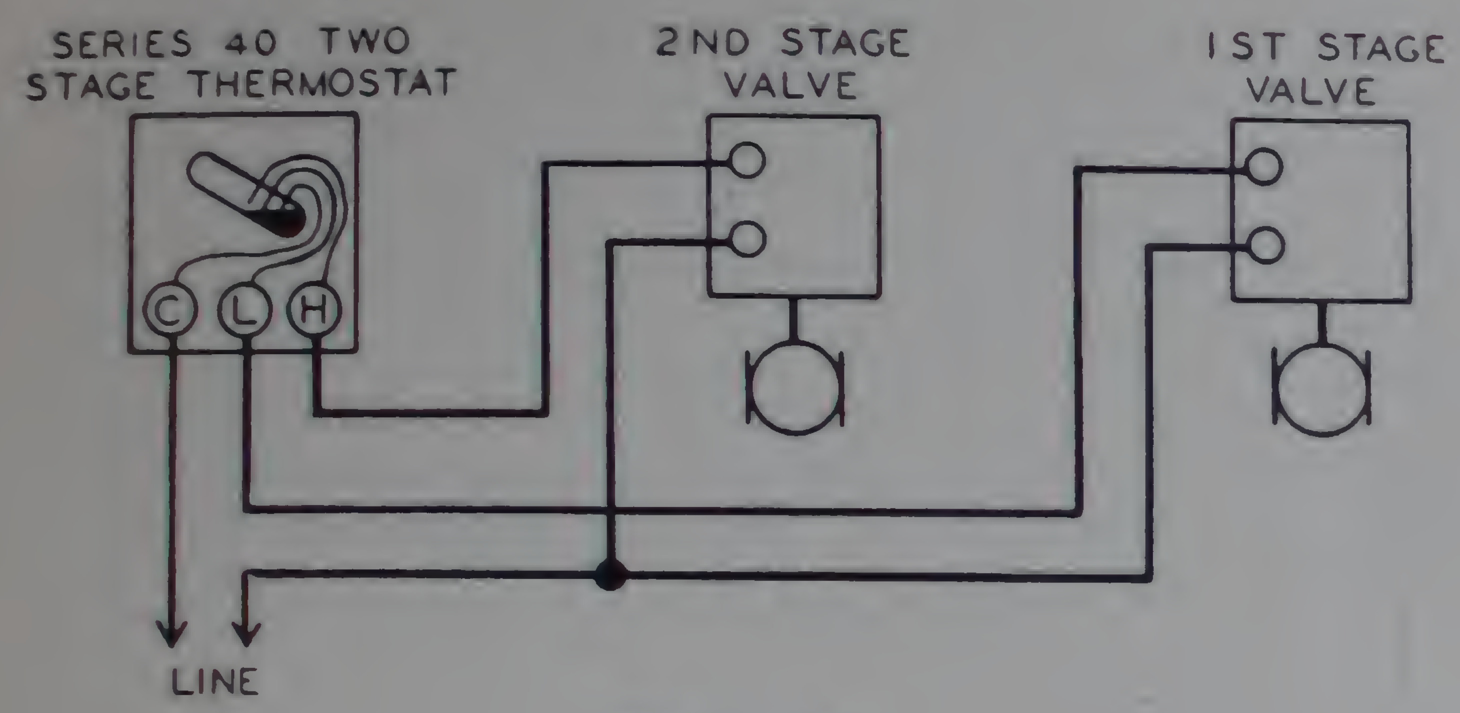


Figure 4

The control circuit for a two-stage controller is shown in Fig. 4. This controller is commonly used in connection with a fan cooling system to turn on two stages of refrigeration in sequence. On a rising temperature, the 3-wire mercury tube first closes the circuit between "C" (common) and "L" (low), opening the first stage refrigerant valve. If the temperature continues to rise, the mercury tube tilts further, closing the circuit to "H" (high) and energizes a circuit to open the second stage refrigerant valve.

SERIES 60

Combinations of Series 60 controls are connected in the same manner as Series 20 controls except that a line voltage instead of a low voltage power supply is used. The controls must be of the mercury tube or snap acting type in order to prevent arcing of contacts switching the line voltage loads.

SERIES 90

Among the most frequently used of the Series 90 control combinations are those shown in the accompanying diagrams.

LOW LIMIT CONTROLS

The most common use of the low limit control with Series 90 Modulating equipment is on central fan ventilating or air conditioning systems where the heating surface is controlled from a room thermostat or a return air controller. The temperature of a space can rise rather rapidly as a result of solar radiation, increased occupancy, etc. Under these conditions the room controller will become satisfied and will close down the steam valve on the heating coil.

If the system is taking a proportion of outdoor air, it is quite probable that after the steam valve has been closed the temperature of the discharge air from the conditioner will drop to a rather low level. The system should be capable of discharging cool enough air to afford cooling during the winter. However, if air is discharged at temperatures below 60° or 65°, cool drafts are apt to occur in certain parts of the space.

A low limit controller in the discharge duct is usually added to this type of conditioning system to limit the temperature of the discharge air. This controller takes over the operation of the steam valve whenever the temperature of the discharge air falls to an uncomfortable level.

Two types of low limit controllers are available. If a low limit instrument with a 135 ohm resistance is used, it will be capable of opening the valve to only 50% of its total capacity. If a 270 ohm resistance is included in the low limit controller, the instrument will be able to open the valve completely. Generally 50% opening of the steam valve by the low limit control provides sufficient heat. It has been found that 50% opening usually gives more satisfactory control during those periods when the steam valve is being controlled by the low limit instrument. The following discussion and sketches will refer to the 135 ohm low limit controller which opens the valve to 50% capacity.

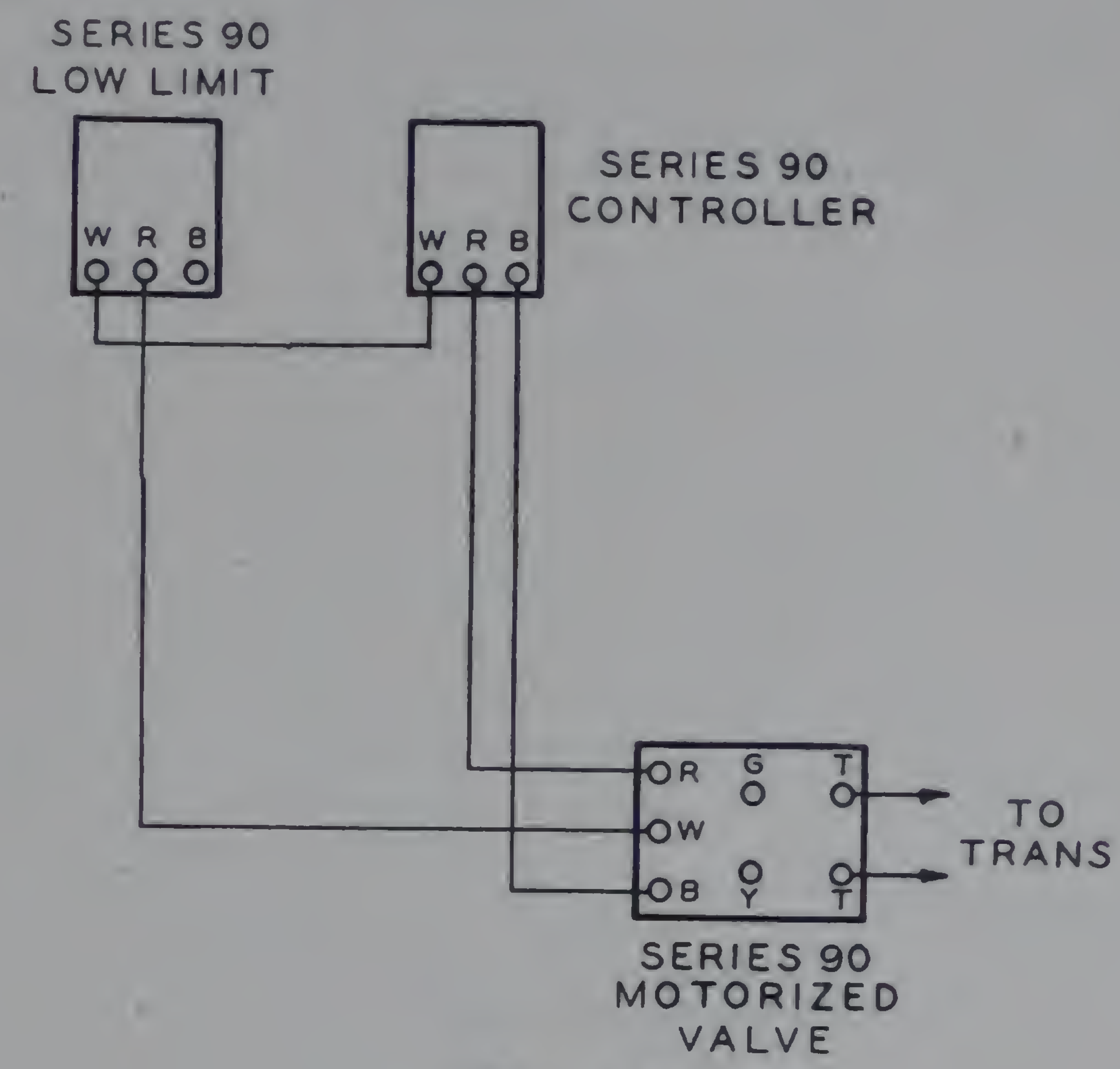


Figure 1

Fig. 1 shows the external wiring connections between a room thermostat, a low limit controller, and a motorized valve.

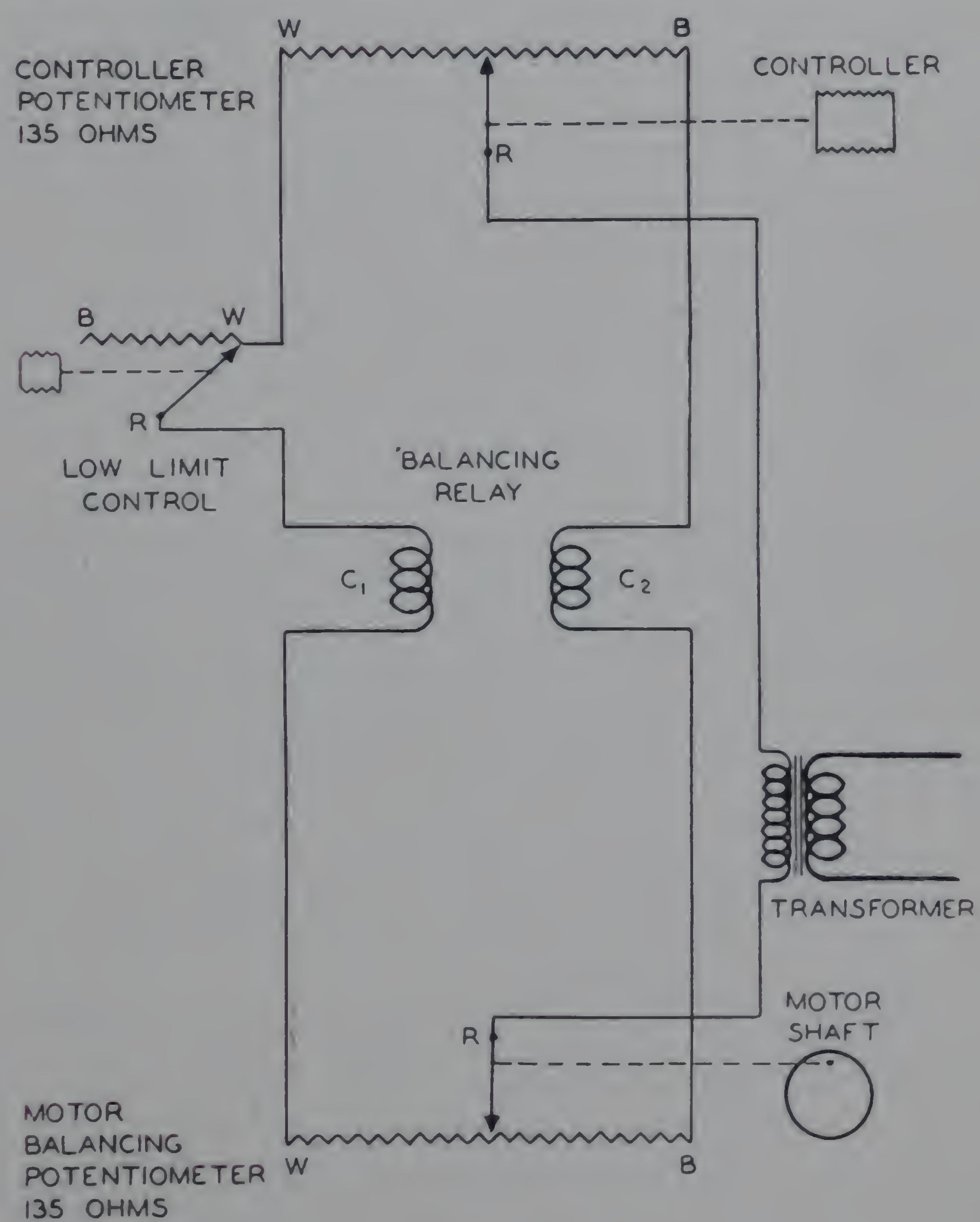


Figure 2

Fig. 2 shows the schematic wiring of the Series 90 control circuit which includes a low limit control. This sketch shows the low limit control as being entirely satisfied. The wiper of the instrument is at the extreme

M-H CONTROL COMBINATIONS

W or warm end of the potentiometer winding, indicating that the temperature of the discharge air is above the setting of the instrument. Under these conditions the controller is free to operate the motor in exactly the same manner as with the straight Series 90 circuit described in the section under "Control Circuits".

So long as the low limit controller remains in this satisfied position, its potentiometer winding will have no effect on the balance or unbalance of relay coils C_1 and C_2. The relay coils will be affected entirely by the action of the potentiometer in the room controller and the balancing potentiometer of the motor.

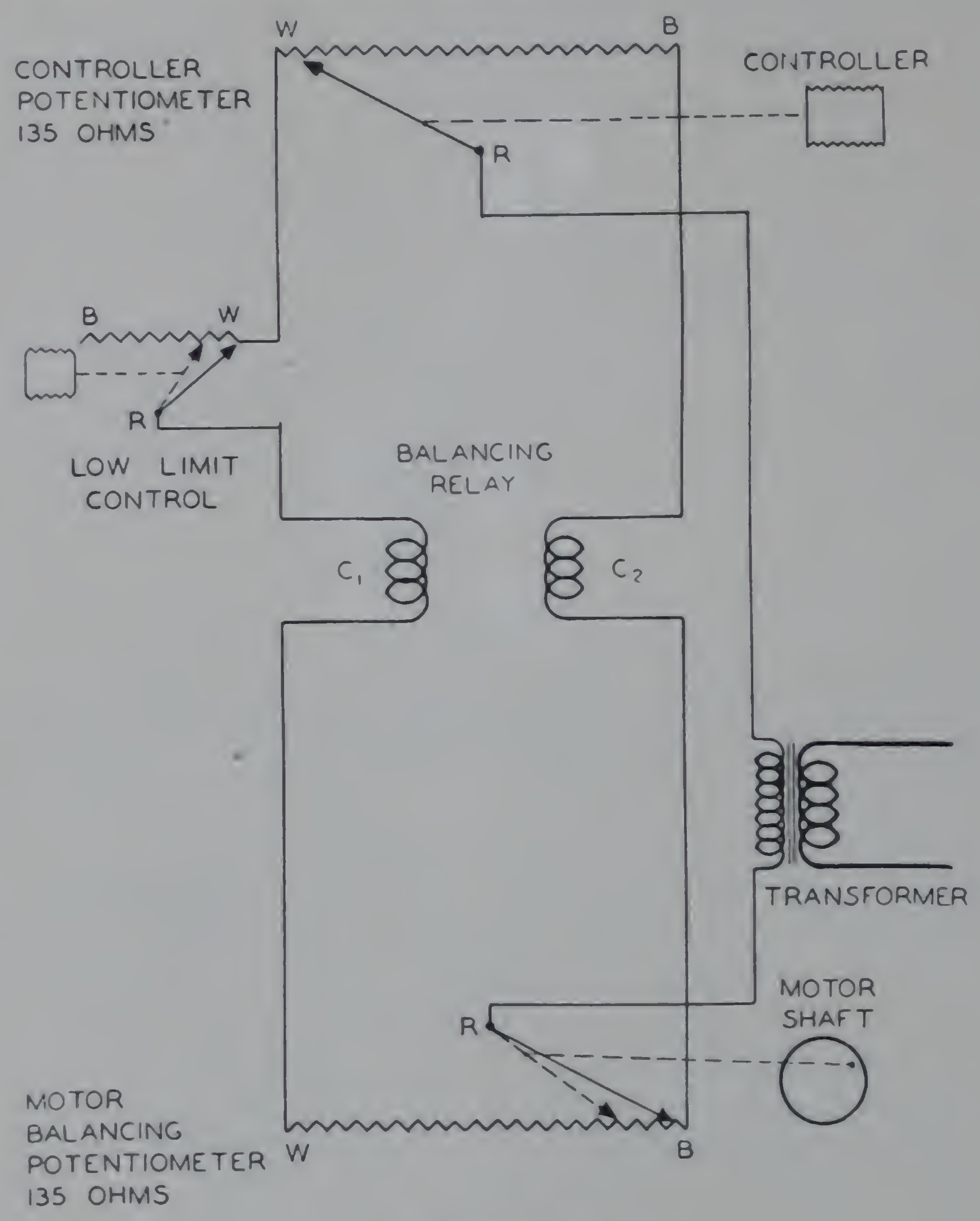


Figure 3

Fig. 3 illustrates a condition where the room temperature is above the setting of the room controller so that its contact blade is making a circuit directly to the W end of the coil. While the low limit control remains satisfied the steam valve will be completely closed as indicated by the position of the balancing potentiometer wiper which is contacting directly the B end of its coil.

If the system is taking in outdoor air the temperature of the discharge from the conditioner will start to drop. As the temperature approaches the setting of the low limit controller the wiper of the instrument will be moved away from the "W" end of the coil. The new position of the contact is dotted in Figure 3.

It will be assumed that the wiper has been moved to a position 25% of its total travel across the coil. This point will split the coil so that there will be 33¾ ohms to the right between the wiper and the "W" extreme. Actually this introduces a new resistance of 33¾ ohms into the left hand leg of the complete circuit. The left leg of the circuit consists of that portion of the controller potentiometer which is to the left of its wiper plus the low limit control, plus relay coil C_1, plus that portion of the balancing relay coil which is to the left of its wiper. Likewise the right leg consists of everything in the control circuit which lies to the right of the two potentiometer wipers.

The circuit will immediately become unbalanced because more current will be flowing down the right leg thru relay coil C_2 than will be flowing down the left leg thru coil C_1. Coil C_2 will exert more force on the relay armature so that one of the motor contacts will be made.

The motor will start to run as soon as the relay contact closes and the balancing potentiometer wiper will then be moved toward the center of the coil. As the wiper moves away from the B end of the coil the right leg of the circuit gains exactly the same amount of resistance as the left leg loses. The motor will of course continue to run until both sides of the circuit have exactly the same amount of resistance, and the relay coils have balanced each other.

HIGH LIMIT CONTROLS

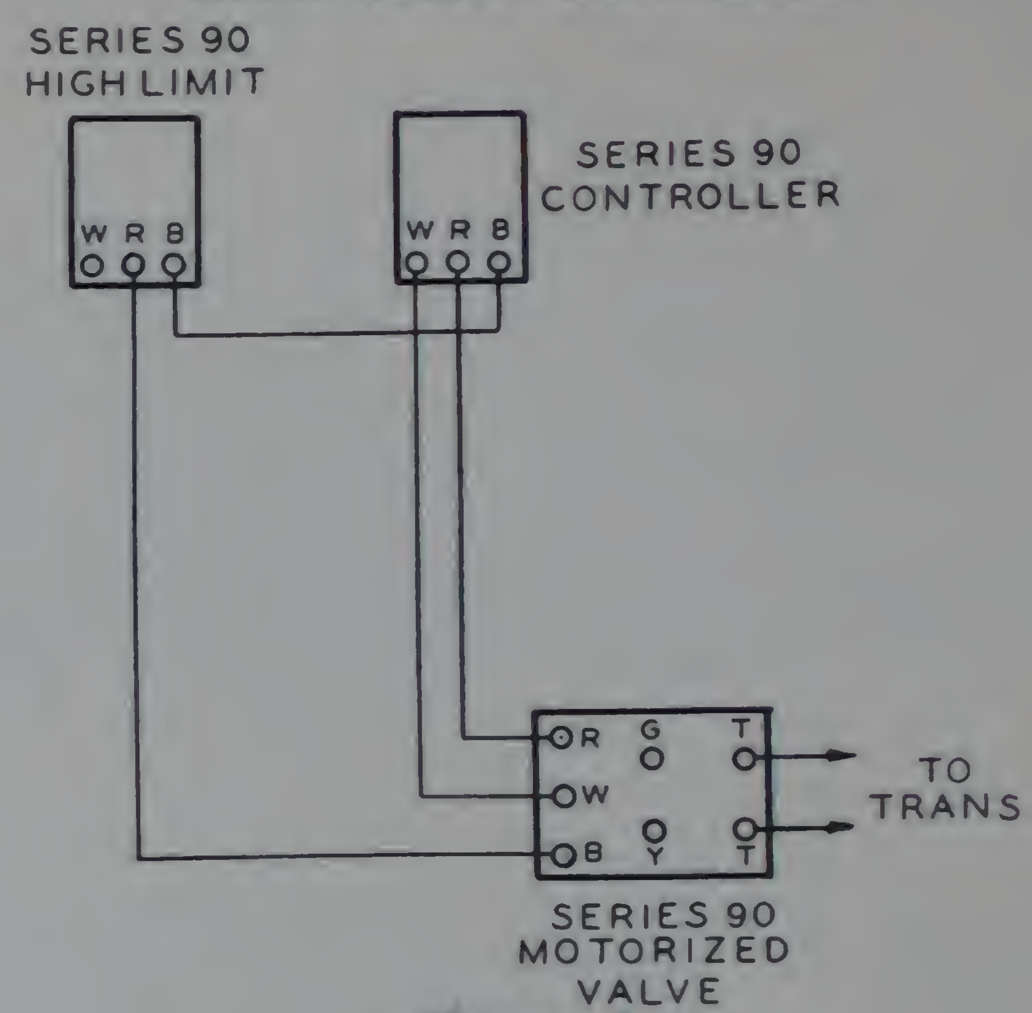


Figure 4

Figure 4 shows the interconnections between the main thermostat control, a high limit controller and a modulating motor. This circuit is often used on a central fan heating system where there is danger of stratification if the discharge temperature rises too high. The high limit control will step in and start to throttle the steam valve whenever the temperature rises too far.

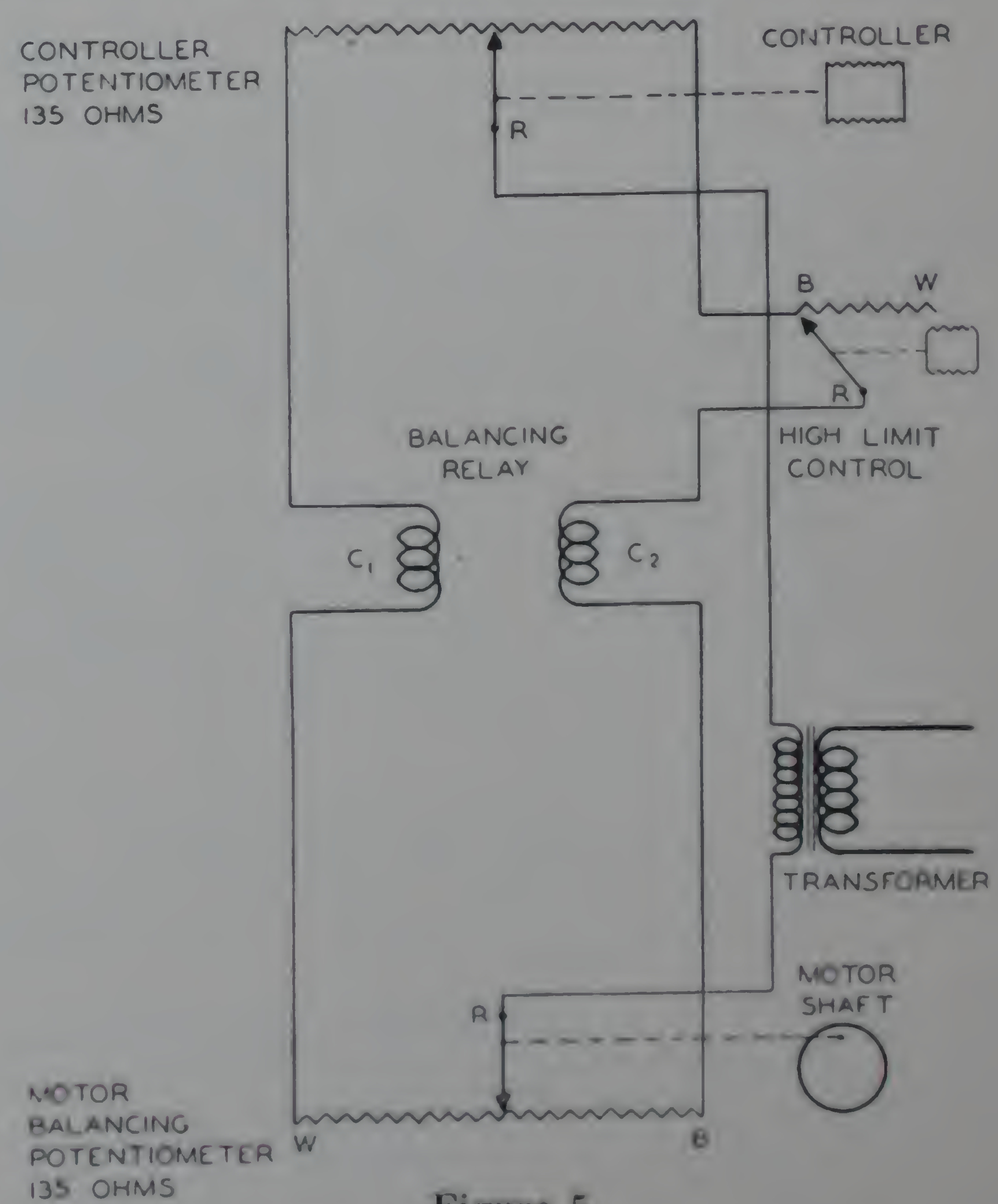


Figure 5

M-H CONTROL COMBINATIONS

Figure 5 shows the schematic high limit circuit. This circuit is very similar to the low limit circuit except that the limit control in this case is connected into the B leg of the control circuit. The operation of the circuit is exactly the same as the low limit.

As the temperature of the discharge air rises, the wiper of the high limit control will move across its potentiometer from the B toward the W side. As this takes place new resistance is placed in the right hand or B leg of the circuit. Relay coil C_1 then becomes energized more strongly than C_2 and the contact is made which will run the motor toward the closed position. The motor will run until the balancing potentiometer wiper reaches a position where the circuit is again in balance.

Two Position Limit Controls

Series 80 (or 40) high or low limit controls may be used in conjunction with Series 90 controls, where it is unnecessary or undesirable that the limit controller operate with a modulating action. In all cases, however, it is very important to note that they must not be used where the temperature of the air in which they are located is affected to any great extent by the opening or closing of the valve or damper motor which they control. If they were used, for example, as a high or low limit control in the discharge air duct to replace the Series 90 limit controllers described in the preceding paragraphs, the steam valve would cycle on and off continuously whenever the temperature of the discharge air fell within the range of the limit controller.

These controllers may be used in a system similar to that shown in Fig. 1, illustrating a circuit for the control

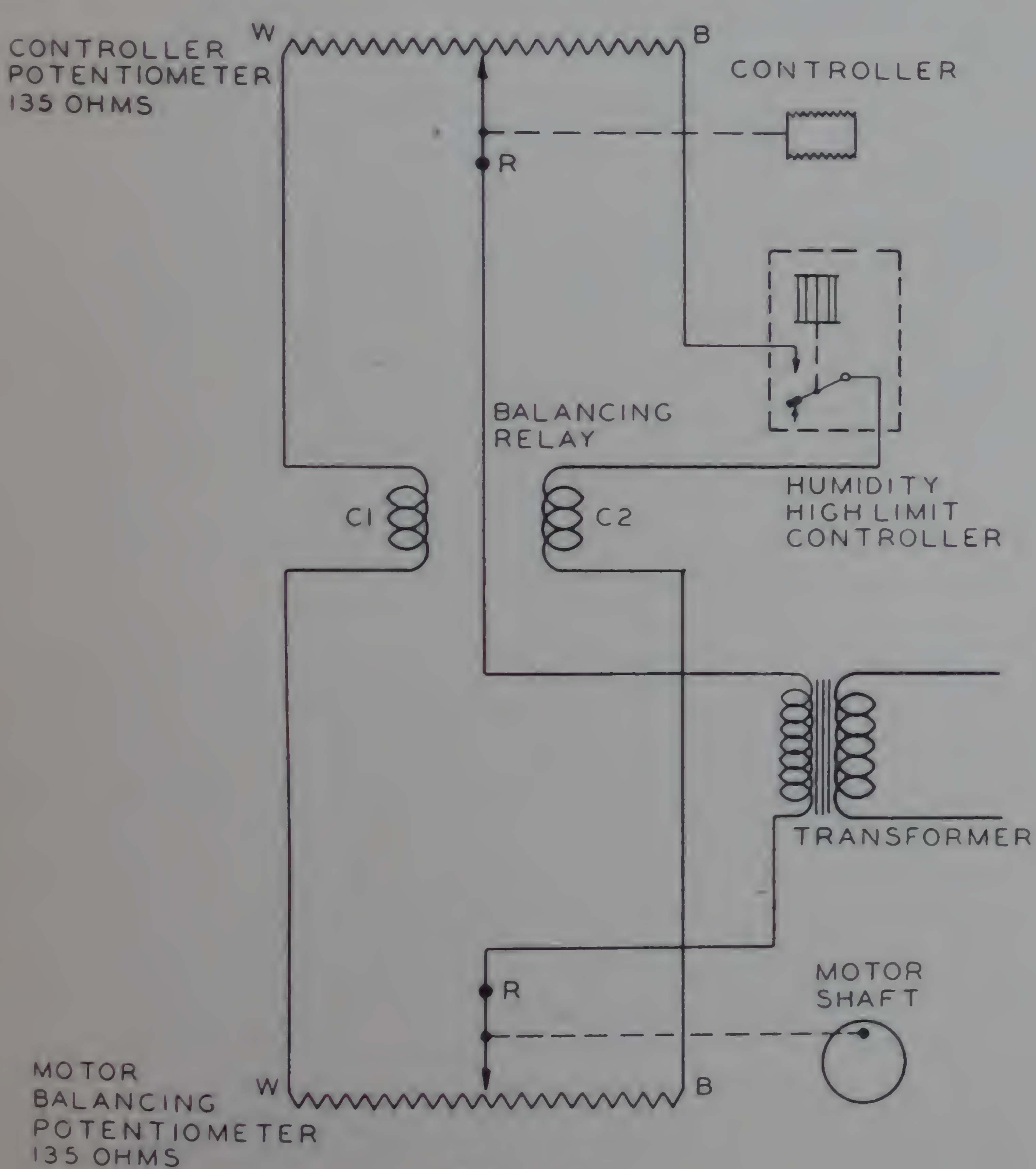


Figure 1

of a motorized brine valve in a fan cooling system. The control system includes a Series 90 temperature controller, located in the conditioned space or in the return air duct, which modulates a three-way mixing valve in the brine supply line to the cooling coil.

The valve is placed in such a manner that when it is in a throttled position it will allow a part of the brine to flow through the cooling coil and by-pass the remainder. It should be noted that the linkage of the three-way mixing valve should be set in such a manner that the valve will open to allow a maximum flow of brine through the coil when the controller is shorted R-W.

In previous discussions dealing with the heating cycle it has been customary to identify the R-W circuit with a closed valve; however, when considering the cooling cycle, this normal procedure must be reversed.

A Series 40 or Series 60 Humidity High Limit Controller can be used in this system to open the valve wide when the relative humidity rises above a predetermined point for which the controller is set. It is wired into the circuit as shown, so that it can break the blue leg of the control circuit. An increase in relative humidity above the control point lengthens the hair element of the controller and trips the switch thereby opening the circuit.

The brine valve will then move to the extreme open position because only balancing relay coil C_1 will be energized.

When the brine valve is in the open position, the temperature of the cooling coil will be reduced to the minimum point. This results in the removal of a greater relative amount of latent than sensible heat from the air passing through the coil, than that which would be removed with the valve in a throttled position.

Unless some form of reheating is provided it is good practice to include a second temperature controller, in a system of this kind, to act as a low limit controller in those localities where humid but mild temperature conditions prevail. This controller should be set a few degrees lower than the main temperature controller, and should be inserted into the circuit in parallel with the humidity controller.

It will make a contact if the temperature should drop too low, thereby shunting out the effect of the humidity controller and causing the brine valve to close.

MANUAL AND AUTOMATIC SWITCHING

It is often desirable to insert manual switches or relays into Series 90 circuits to accomplish certain functions.

A Single Pole Single Throw switch is connected as shown in Figure 2. The motor will normally be under the control of the controller whenever the switch is closed. When the switch opens the motor will run to one extreme depending upon which side ("B" or "W") of the control circuit is interrupted.

If the circuit through the "Blue" side is broken the motor will run to the same position as though the controller wiper were at the extreme "W" end of its potentiometer. The exact opposite will result if the "White" side of the circuit is interrupted.

M-H CONTROL COMBINATIONS

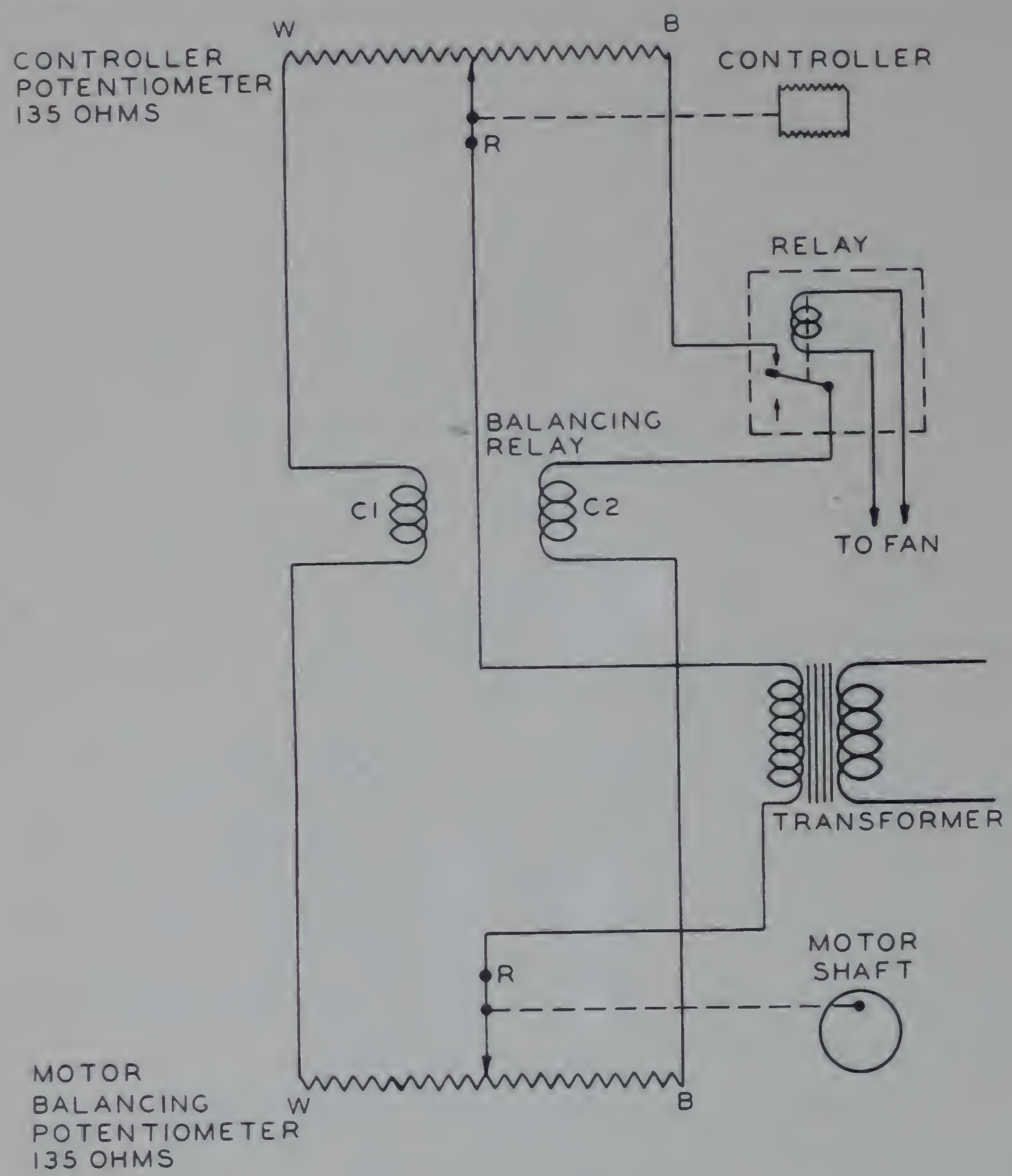


Figure 2

A circuit of this kind is often used in connection with a fan heating system to control the relative humidity during the winter cycle. The humidity controller is mounted in the return air duct or within the heated space, while the motorized valve is installed in steam supply line to a grid or pan type humidifier. The relay is energized by fan motor circuit, so that the steam valve is always driven to the closed position when the fan is shut down. If this were not done, the conditioner might become flooded with steam or vapor during the period of shutdown, since without circulation of the humidified air, the humidity controller would not become satisfied and close off the valve.

Recycling Step Control

The circuit shown in Fig. 3 is that of a Series 90 step controller, which, under the command of the temperature controller, cuts in just sufficient refrigeration capacity to meet the cooling load requirements in a fan system.

The step controller consists of a group of mercury switches operated in sequence by cams which are driven by a modulating motor. The mercury switches are wired into the "pull-in" coils of the compressor starters as shown. As the temperature of the conditioned room rises, the temperature controller operates the step controller toward the "on" position and cuts in the first compressor. On a further rise in temperature, additional compressors are cut in to meet the demand for cooling.

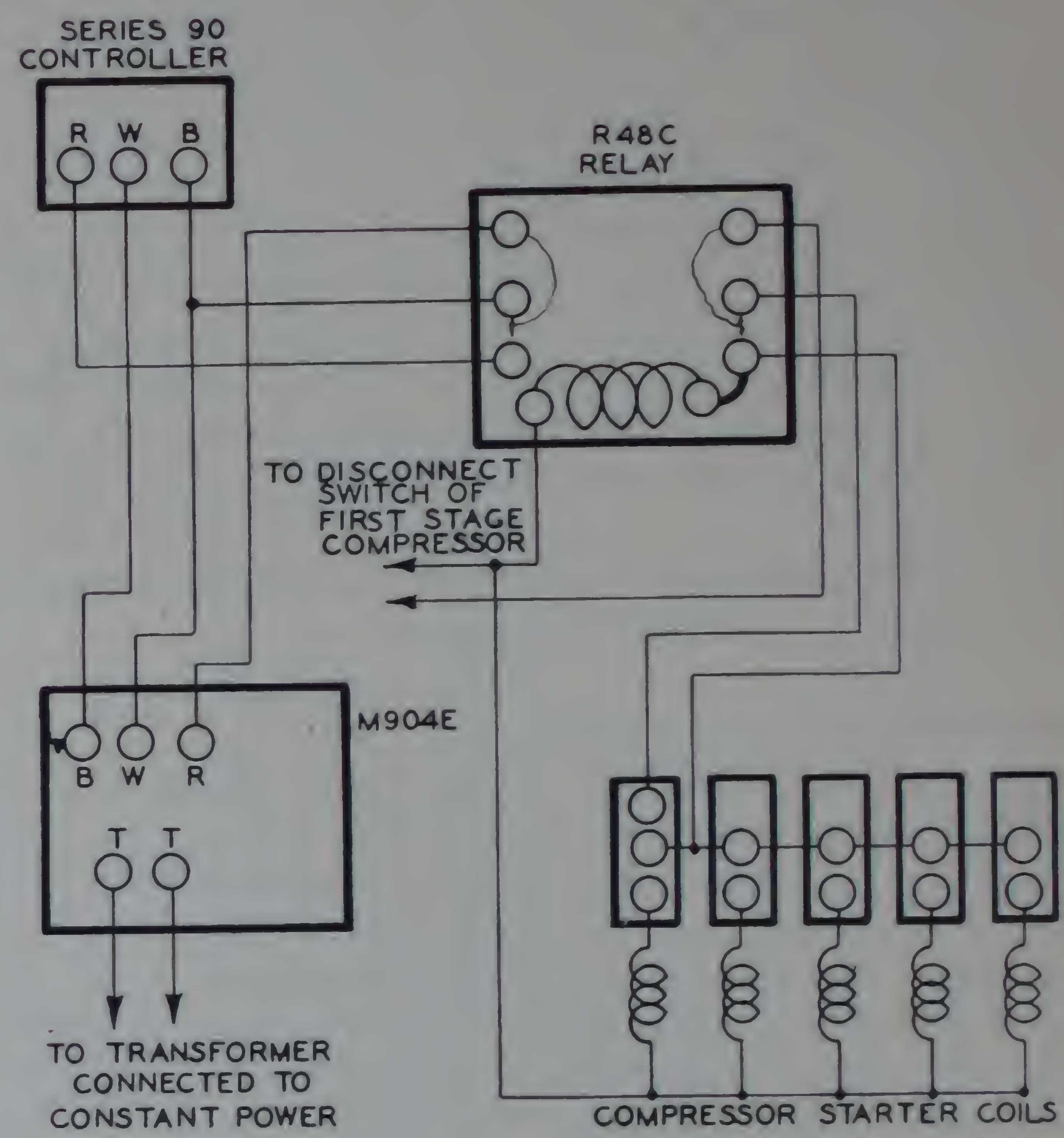


Figure 3

The complete compressor starters and power wiring are not shown in Fig. 3 in the interest of simplicity. The power supply for the compressor starter coils is often taken from the fan circuit or through relay energized from the fan circuit so that the compressors will not run when the fan is shut down.

An additional feature is provided in this circuit which prevents the flow of an excessive amount of current in the power supply line to the compressors when the fan is started or immediately following an interruption in power supply. This is quite important in most instances, since the starting current of the compressors is considerably higher than the normal running current. Electric power service lines are usually sized for normal rather than extreme loads. Therefore, if all of the compressors were allowed to start at the same time instead of in sequence, it would probably result in serious damage to fuses and power transformer equipment.

The step controller is recycled after a system shutdown or power interruption, by means of the relay and first step switch on the step controller. The relay contacts are connected into the temperature controller circuit so that when the relay drops out due to power failure or the opening of the first compressor disconnect switch, the step controller is driven to the "off" position breaking the circuit to all compressor starters. Should the power interruption be only momentary, the step controller will still prevent restarting of the compressors until after it has returned to the "off" position, since the starting or "pull in" circuit of the relay is not completed until after all other switches are opened.

M-H CONTROL COMBINATIONS

Discharge Air Control of Outside Air Dampers

Figure 4 shows the interconnections between equipment used in the system for discharge air control of outside air dampers as described on page 24 of Section 4.

The return air controller includes both a potentiometer and a set of snap acting S.P.D.T. contacts. The potentiometer controls the Series 90 steam valve in conjunction with one potentiometer of the discharge controller. If the temperature of the discharge air drops too low the discharge air controller will add resistance to the W circuit to the motor thereby tending to open the valve.

If the return air temperature rises above the range of the potentiometer in the return air controller, the snap contacts will make between R and W. If the low limit control in the discharge air has allowed the valve to close, a circuit will be established between R and W of the valve auxiliary switch. In this way the Series 80 relay will be energized.

When the Series 80 relay is energized the discharge low limit control will be shunted out of the valve circuit and will be unable to open the valve. With the relay energized, the second potentiometer in the discharge controller will control the outdoor air damper. Enough additional outdoor air will be admitted to keep the temperature of the discharge air at a low enough level to provide cooling.

When the return air temperature again drops to its normal range, the Series 80 relay will be de-energized and the outdoor air damper motor will return to its fixed minimum position.

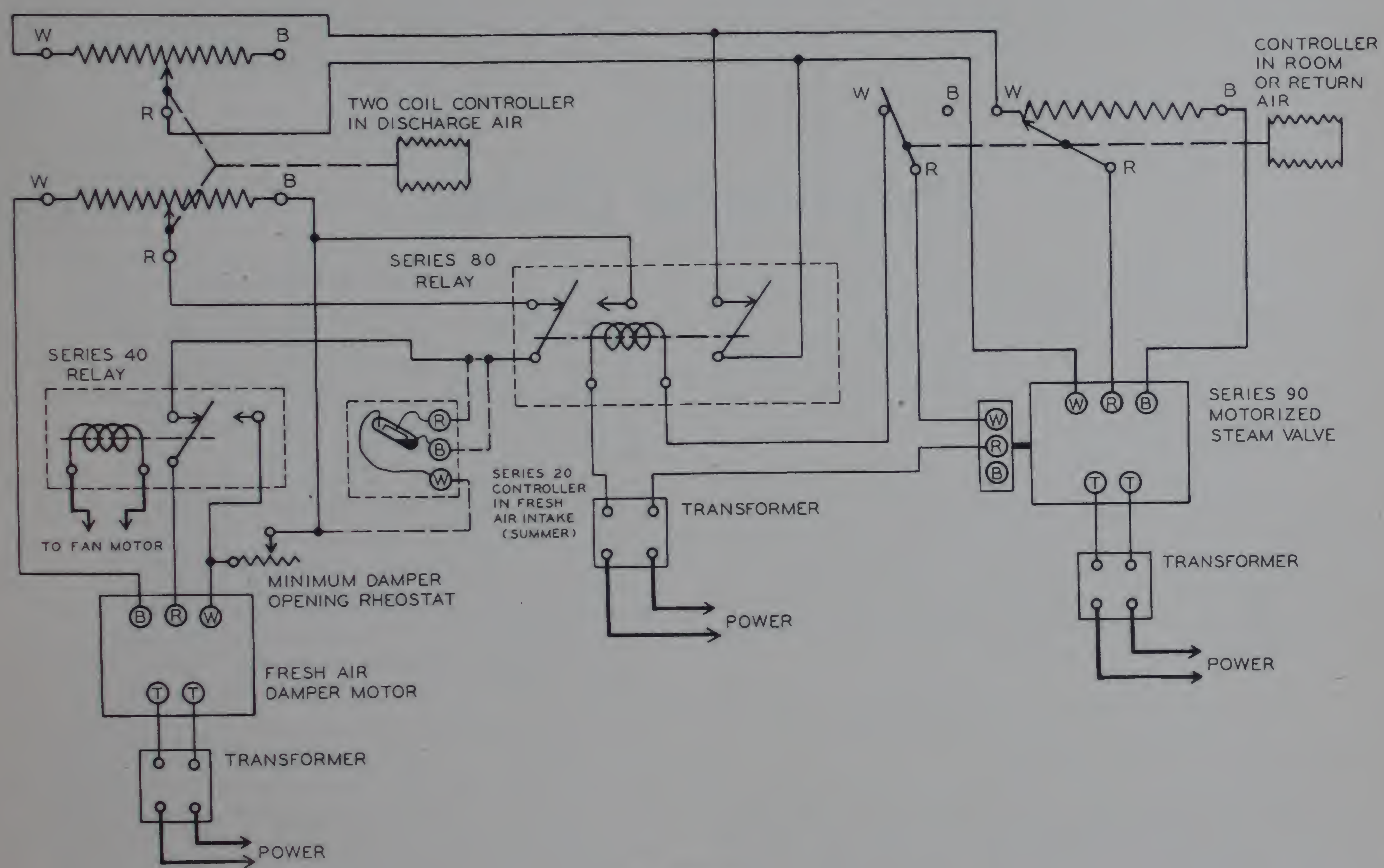


Figure 4

Direct Outside Air Control

The connections shown in figure 5 apply to the system of outdoor air damper control discussed on page 24 of Section 4.

The return air controller or room thermostat incorporates two potentiometer coils, set for sequence operation. One coil modulates the steam valve, and the other coil acts as a cooling control to modulate the intake damper from the minimum to the wide-open position whenever the space or return air temperature indicates a need for cooling.

An auxiliary potentiometer on the steam valve adds resistance to the white leg of the motor as the valve modulates from wide-open to ¾ open; the intake damper is thereby modulated from closed to a minimum open position. This minimum position is adjustable from 0 to 50 percent, by means of the minimum position switch.

The "cooling" coil of the temperature controller is adjusted so that it adds additional resistance to the white leg of the intake damper motor as the temperature rises above the point at which the steam valve is completely closed. As this resistance is added, the intake damper is positioned between its minimum position and 100 percent open to provide cooling.

A high limit controller in the outdoor air shorts out the "cooling" coil of the controller at any time the outdoor air is too warm to be effective for cooling; the intake damper is thus returned to its minimum position regardless of space temperature.

M-H CONTROL COMBINATIONS

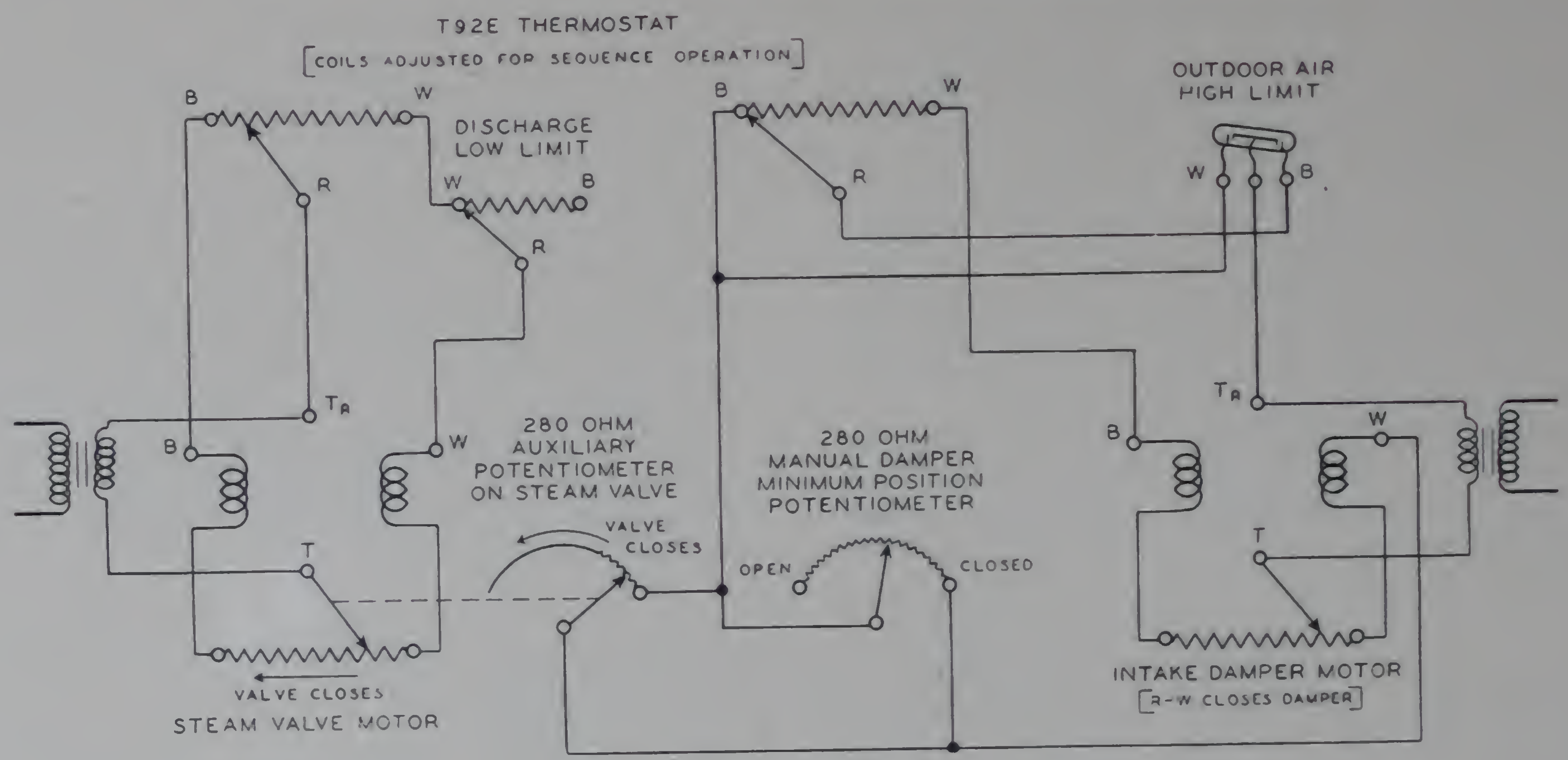


Figure 5

Compensated Control

It is often desirable to automatically change the control point of an instrument controlling conditions in one media in accordance with the conditions of a second media. For example on a summer cooling installation, authorities agree that more comfortable and healthful conditions will prevail if the indoor temperatures are raised slightly as outdoor temperatures rise.

The M.H.R. Series 90 circuit with its balancing principle furnishes an ideal means for resetting an instrument electrically. By introducing proper resistance, the control circuit can be biased so that a new control point is set up at the controller. No mechanical linkages are necessary. The compensator or master controller is merely connected into the control circuit electrically.

COOLING CYCLE APPLICATION

Compensated Dry Bulb Control.

The inside control point is raised according to a predetermined schedule as the outdoor temperature rises. For example, a schedule can be established which will call for an inside temperature of 75° when the outside temperature is 75°. At the high end of the schedule an outside temperature of 100° will call for an inside temperature of 85°. With this schedule the inside temperature would be raised 1° for each 2½° rise in outside temperature.

The use of compensated control on cooling systems tends to eliminate any shock which might be experienced during severe weather when a person passes in or out of a cooled space.

HEATING CYCLE APPLICATION

Compensated Hot Water Control.

Hot Water heating systems can sometimes be controlled in a satisfactory manner by varying the boiler water temperature with outside temperature. The boiler water temperature may be raised from around 100° to about 200° as the outside temperature drops from 65° to 0°.

THEORY OF OPERATION

In the discussion of compensated control it must be realized that the compensator or master controller merely shifts the control point of the controller or sub-master. At each new control point the controller must be able to operate the motor from the fully closed to the fully open position while the control wiper moves across only a fraction of its potentiometer winding.

Assume that on a cooling system the following schedule is required. Control the inside temperature at 75° when the outside temperature is 75°. Raise the inside control point one degree for each two and one half degree rise in outside temperature until the inside temperature reaches a maximum of 85°. Maintain the inside temperature within a differential of 3° for each inside control point.

For example, if the outside temperature is 90°, the inside temperature shall range between 79½° and 82½°.

The foregoing example gives rise to the following definitions:

TOTAL DIFFERENTIAL is the number of degrees between the high and low point of the controller schedule. In the example it is equal to the difference between 85 and 75 which is 10°. This amounts to the change in temperature required to move the wiper completely across the potentiometer coil.

OPERATING DIFFERENTIAL is the number of degrees change at the controller which will cause the motor to operate thru its entire stroke. In this example the operating differential equals 3°.

OPERATING DIFFERENTIAL RATIO is the ratio of the OPERATING DIFFERENTIAL to the TOTAL DIFFERENTIAL. The ratio in the above example is 3 to 10 or .3.

Figure 1 indicates schematically a compensated circuit wherein the single coil instrument which is at the top of the sketch is the compensator. Resistances in parallel with the compensator and balancing potentiometer of the motor have been added to the circuit. These resistances are necessary so that the controller will be able to get full travel from the motor when only a fraction of the controller's total resistance is used.

The controller in a compensated cicuit consists of two 135 ohm coils which are connected into the circuit so that as resistance is subtracted from one leg of the circuit an

COMPENSATED CONTROL

equal amount is added to the opposite leg. Since the balancing potentiometer of the motor is also 135 ohms, the wipers of the controller would have to move completely across their potentiometer coils in order to operate the motor from one end of its stroke to the other if no resistance were placed in parallel with the motor potentiometer. Placing a resistance in parallel with the motor balancing potentiometer in effect reduces the resistance of the potentiometer. In this way it becomes necessary for the motor to move the balancing potentiometer wiper a greater distance in order to counteract the effect of an unbalanced condition at the controller.

By placing the correct amount of resistance in parallel with the balancing potentiometer in the motor, it is possible to make the motor operate thru its complete stroke while the controller moves thru any given fraction of its total travel. If the ratio of the operating to the total differential as defined above is .3, a certain resistance can be placed in parallel with the motor potentiometer so that .3 of 135 or 40.5 ohms variation in each coil of the controller will cause the motor to modulate thru its entire stroke.

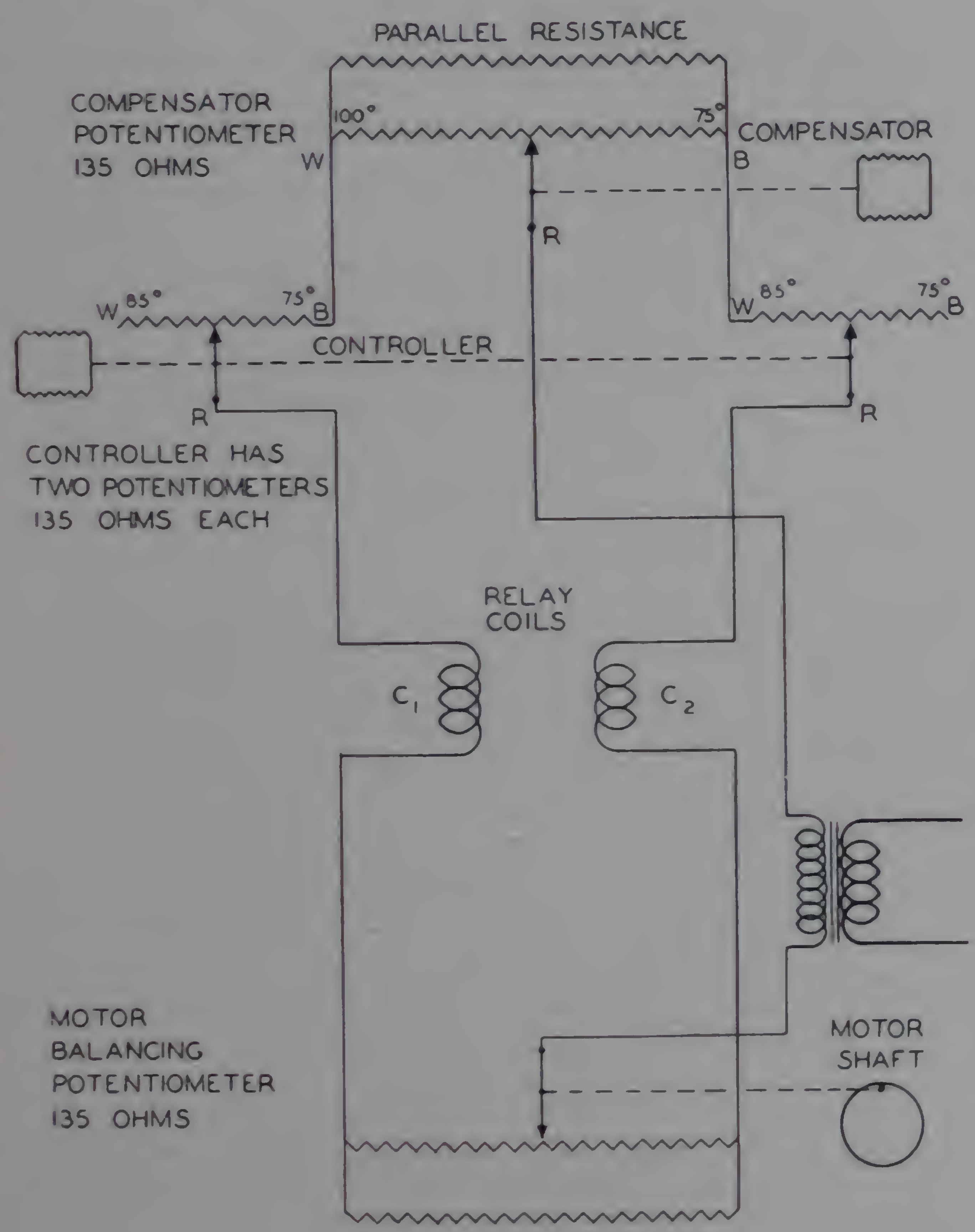


Figure 1

Figure 2 shows the position of the motor when the controller is at the center of its operating differential. The dotted positions of the wipers indicate that the motor will be completely closed when the controller is at the high end of its operating differential. Figure 3 is similar to Figure 2 except that it shows the motor in the open position when the controller is at the low end of its operating differential.

It can readily be seen that a resistance in parallel with the compensator will be necessary or the compensator will have the same amount of control over the motor as the controller itself. When the proper resistance is placed across the compensator this instrument can move the operating differential of the controller to any position on the controller winding.

Consider first a condition when the compensator is at the middle of its winding which would mean that the outside temperature was 87½° in the example used above. This means that the operating differential of the controller would be equally divided on each side of an 80° inside temperature. As indicated in Figures 2 and 3, the system can be completely in balance whenever the control wipers are within the operating differential of the inside controller. The motor potentiometer can under these conditions find a position which will balance up the circuit and stop the motor at some intermediate position. However, when the inside temperature rises above 81½° the motor will be completely open and calling for all available cooling. The motor will remain in this position until the temperature has been brought below 81½°. Likewise if the inside temperature should drop below 78½° the motor will be closed calling for no cooling until the inside temperature has again reached the range of the operating differential. The above discussion assumes that the compensator is at 87½° outside temperature.

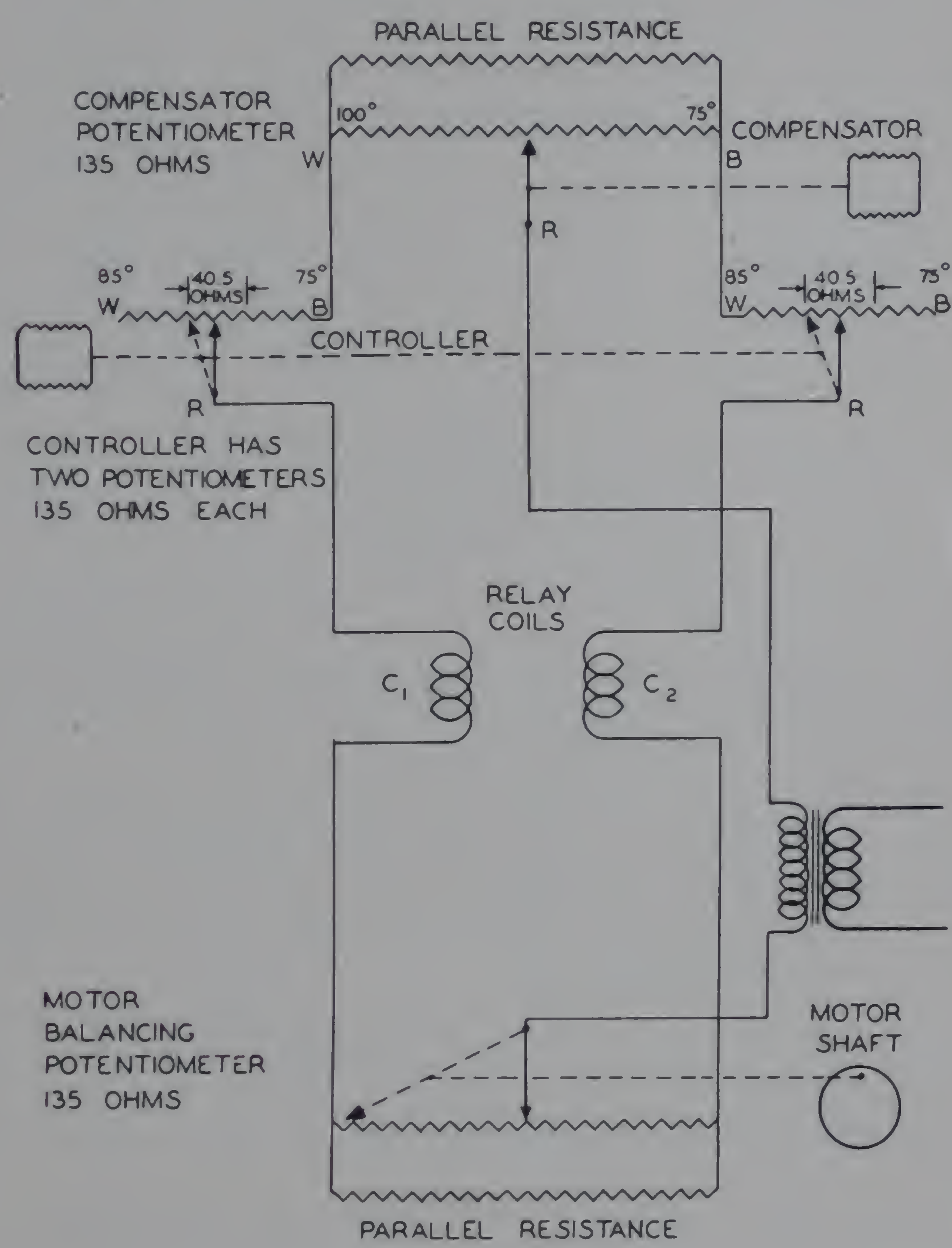


Figure 2

Figure 4 shows the position of the controller and the motor for the same conditions as illustrated in Figures 2 and 3. The inside temperature is at 80° and the motor is about 50% open. The outside temperature has however risen to 93° as indicated by the position of the outside compensator.

The position of the compensator's wiper blade unbalances the circuit so that more current is now flowing down the left hand leg of the circuit thru relay coil C_1. This condition unbalances the relay armature and makes the contact which will run the motor toward the closed position. The operating differential is moved to a new position on the controller windings which will be between 80½° and 83½°. The motor will run to its tight closed position as indicated by the dotted contact blade in Figure 4 because

COMPENSATED CONTROL

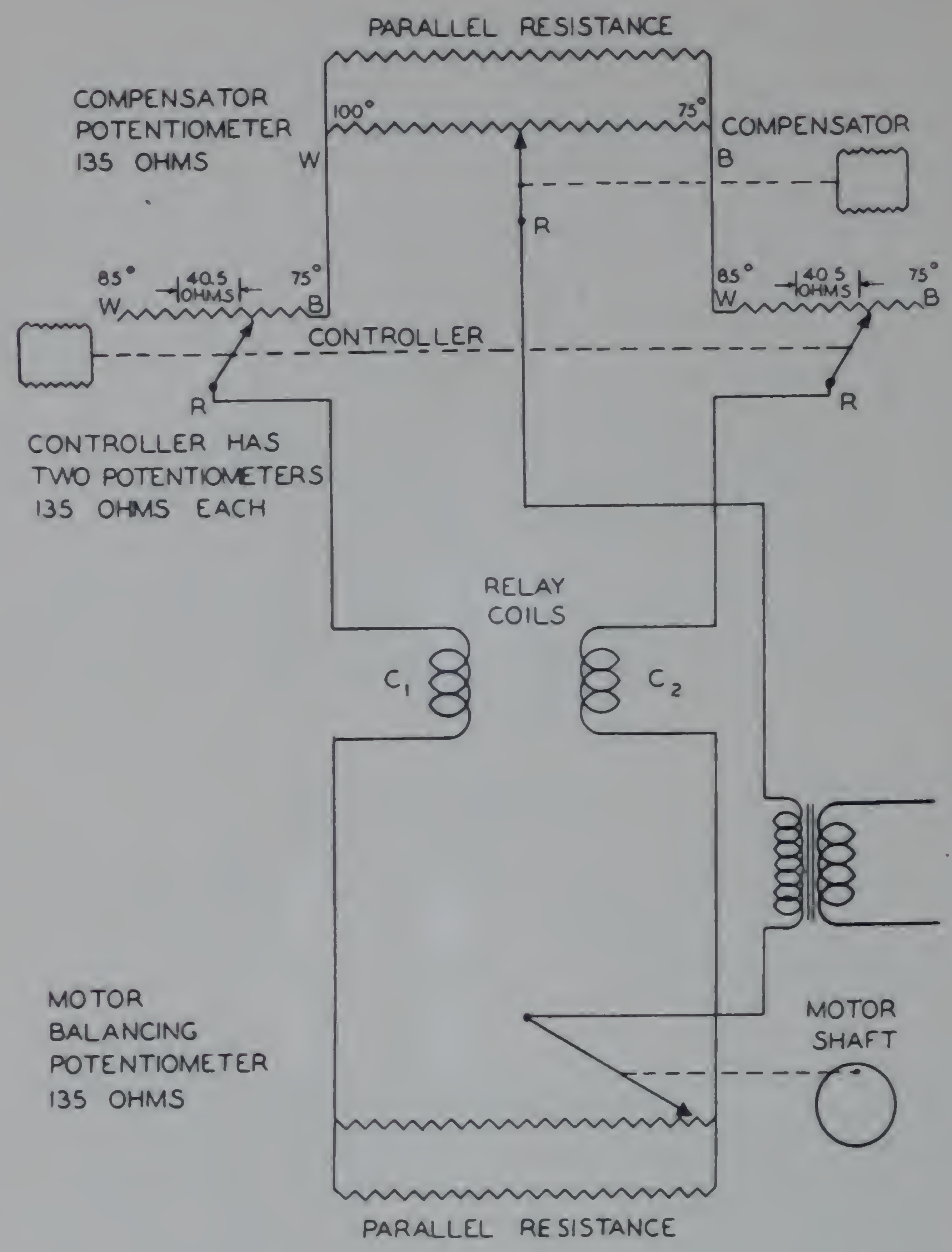


Figure 3

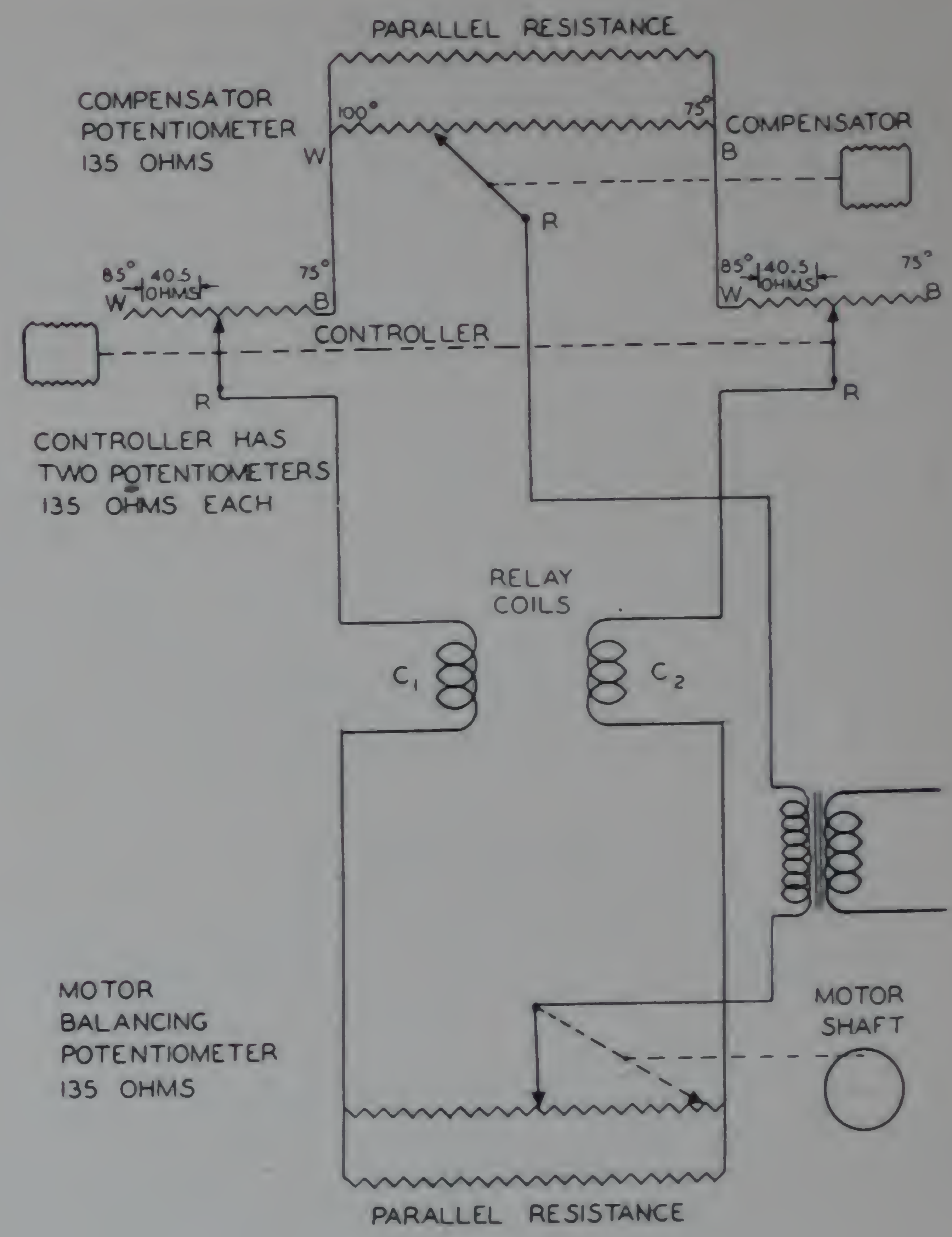


Figure 4

the temperature at the inside thermostat is now below its operating differential. The new range of the operating differential is indicated in Figure 4.

Since the motor is closed the space will no longer be cooled and the temperature will begin to rise. When the inside temperature reaches 80½° the motor will begin to open and will be positioned entirely at the command of the inside controller as the temperature varies throughout the operating differential.

In a similar manner the **operating differential** of the controller is shifted to various positions throughout the **total differential** of the controller as the wiper of the compensator moves to new positions on its potentiometer.

SETTINGS FOR COMPENSATED CONTROL

In order to select the proper values for the parallel resistances at the compensator and at the motor, the ratio of the operating differential to the total differential of the controller must be determined

Cooling

For compensated cooling control it is only necessary to select a suitable operating differential which may be 3° and divide this value by the total differential to be covered. The value of the total differential on a cooling system equals the number of degrees between the lowest temperature in the schedule and the highest temperature in the schedule. In the example which has been used throughout this discussion, the total differential equals the difference between 85° and 75° or 10°. The ratio then as explained before is 3 to 10 or .3.

In setting up such a system it is necessary to use as the controller an instrument with an adjustable differential. The low point, in this case 75°, is set on the main scale of the thermostat. The amount of **total differential** (10°) is then set on the differential scale. With these settings the wipers of the thermostat will be moved across the entire active winding of their potentiometers as the temperature varies between 75° and 85°.

It is necessary to have an adjustable differential on the compensator so that a wide operating range can be set on the instrument. For example — the wiper may have to move across the potentiometer winding as the outside temperature goes from 75° to 100° which would require a 30° differential setting on the instrument.

In setting the instruments for compensated control of a heating system the total differential of the controller is determined in a slightly different manner than for cooling control. When determining the control ratio and also when setting the controller it is necessary to add the amount of the desired operating differential to both ends of what would be considered the total differential if it were a cooling installation.

As an example consider compensated discharge control where the discharge temperature is to vary from 65° to 85° as the outside temperature drops from 65° to 30°. Since this is a discharge control system the operating differential of the discharge controller should be at least 6°. The total differential should then be considered as 20° plus two times 6° which makes 32° in all. The 20° is the difference between 65° and 85° which are the high and low ends of the discharge controller schedule.

Since the operating differential has been chosen as 6°, the ratio of operating to total differential is 6 to 32 or .19. Such a ratio would usually be considered as .2 and the corresponding resistances would be used.

COMPENSATED CONTROL

The discharge controller in this example should be set at 59° with a differential setting on the instrument of 32°. In this way an additional 6° is added at both ends of the total range of the controller.

Parallel Resistances

The following table gives values for the resistances to be used with .2, .3, and .4 ratios of operating to total differential of the controller. These three ratios will handle practically all the applications for compensated control systems. Control ratios smaller than .2 should be avoided whenever possible. The ratio can easily be increased by widening the operating differential slightly. This procedure will not materially affect the control results.

Ratio of Operating of Total Differential	Motor Resistance Value	Motor Resistance Part No.	Compensator Resistance Value	Compensator Resistance Part. No.
.2	43 ohms	20303	390 ohms	20309
.3	72 ohms	20304	290 ohms	20308
.4	113 ohms	20305	204 ohms	20307

Note: For two position compensated control that is when an R92 relay is used, one 1600 resistance should be placed in parallel with the potentiometer of the compensator. The operating differential of such a circuit will be about 10% of the total differential of the controller.

TWO-POSITION COMPENSATED CONTROL

Although the majority of applications for compensated control call for modulating response, it is often desirable to compensate the control point of equipment controlled in an "on" and "off" manner. For example, a compressor on a comfort cooling installation might be started and stopped at the command of a room thermostat which in turn would have its control point automatically adjusted by a compensator in the outdoor air. The inside thermostat and outside compensator would in this case be connected to a series 90 relay which would take the place of a modulating motor.

Figure 7 shows the arrangement of controller, compensator, and relay for two position compensated control. The main difference between this arrangement and that used for modulating control is that the balancing potentiometer of the motor has been eliminated.

The Series 90 relay (type R92B) consists of a balanced type of relay mechanism identical to the one used in the modulating motor. This relay affords S.P.D.T. switching action which in turn controls a Series 30 relay unit for switching the load. Only the coils of the balanced relay are shown in Figure 7.

In Figure 7, if the current in the left leg of the circuit (that leg which connects to the B relay terminal) becomes greater than the current in the opposite leg, the balanced relay will make a contact which will energize the load relay. This will start the compressor.

If the wiper of the compressor moves toward the "W" end of its potentiometer, indicating a rise in outdoor temperature, the Series 90 relay will make the contact which de-energizes the load relay. The inside temperature will then start to rise and the compressor will remain "off" until the wipers of the controller have reached a position on their potentiometers which will unbalance the relay in the opposite direction. The compressor will then be cycled at the command of the controller as the temperature in the space rises and falls.

A compensator resistance as shown in Figure 7, is placed in parallel with the potentiometer of the compensator. This resistance is necessary to prevent the compensator from taking control away from the controller at any time. A value of 1600 ohms is satisfactory for this purpose.

COOLING CONTROL

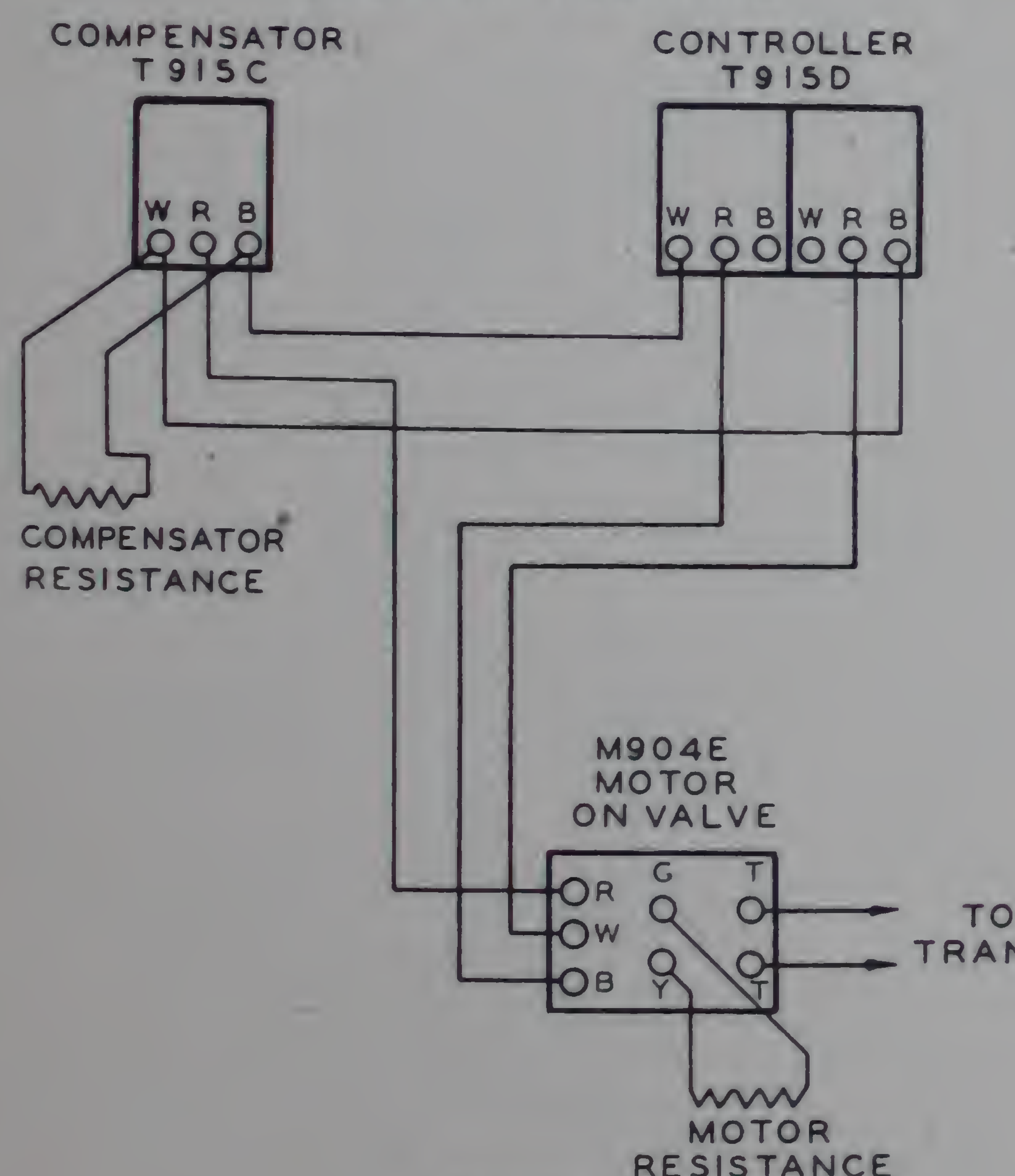


Figure 5

Fig. 5 illustrates the connections between the compensator, controller and motor when compensated control is applied to the cooling cycle.

HEATING CONTROL

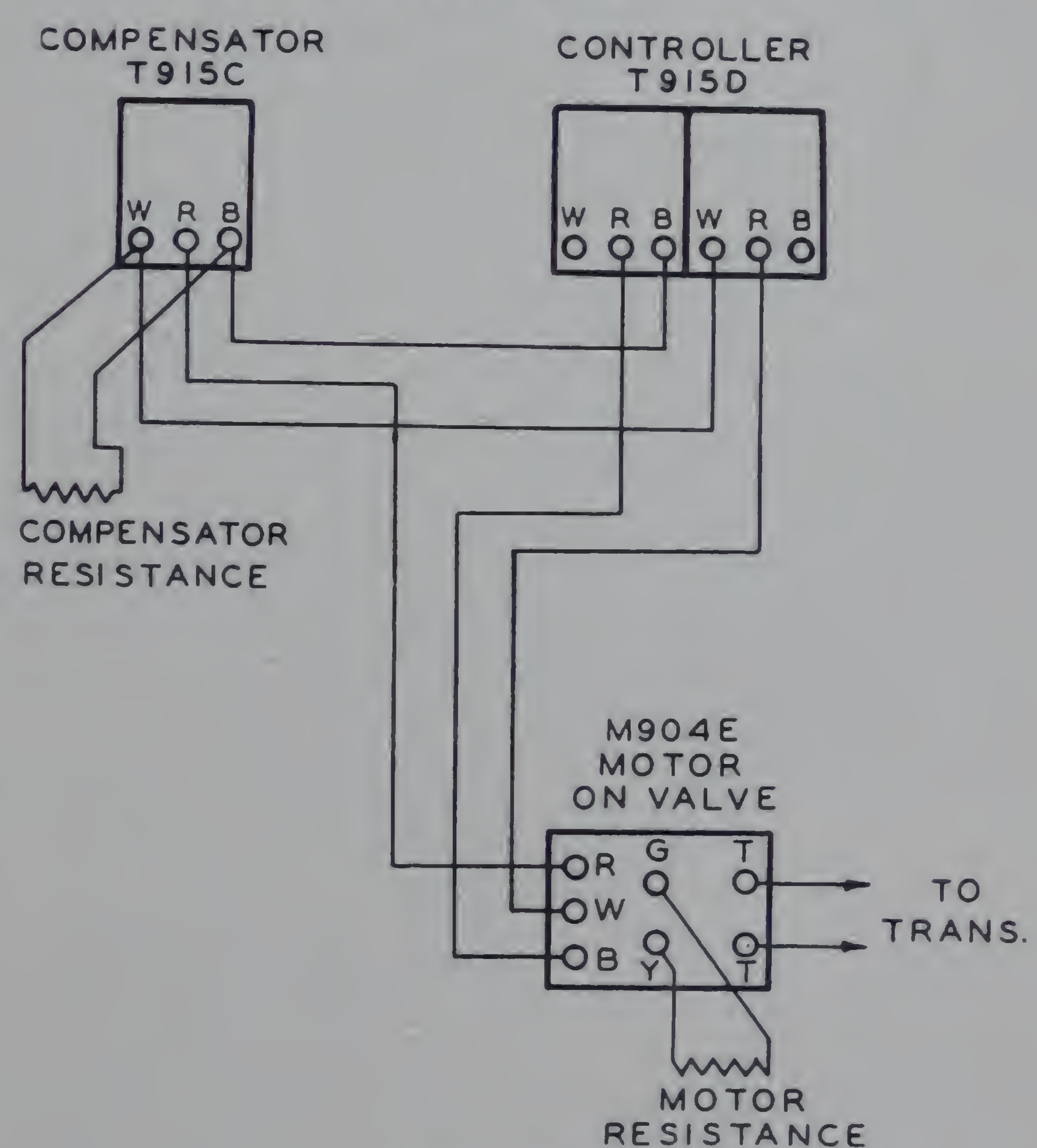


Figure 6

Fig. 6 illustrates the connections between the compensator, controller and motor when compensated control is applied to the heating cycle.

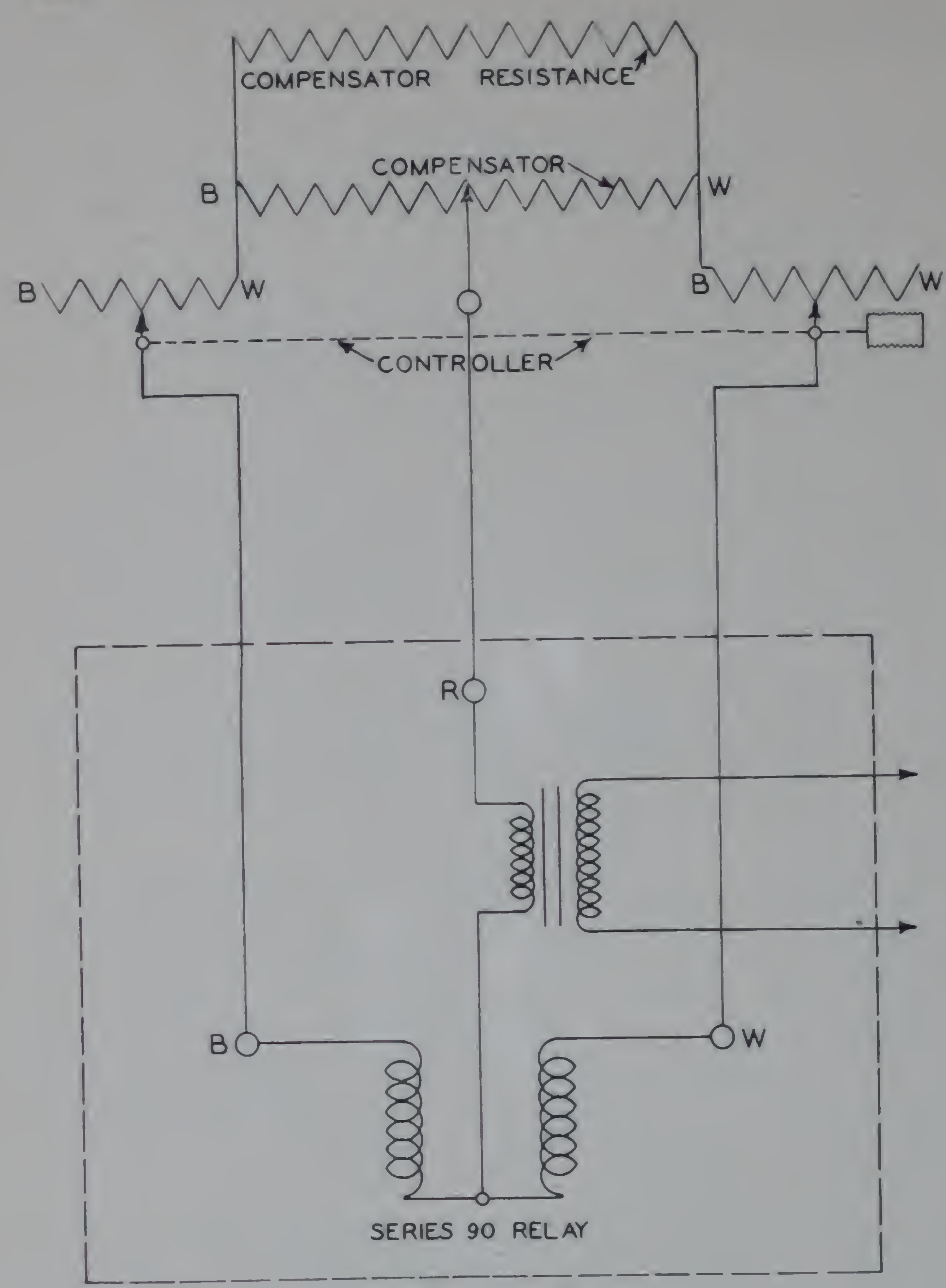


Figure 7

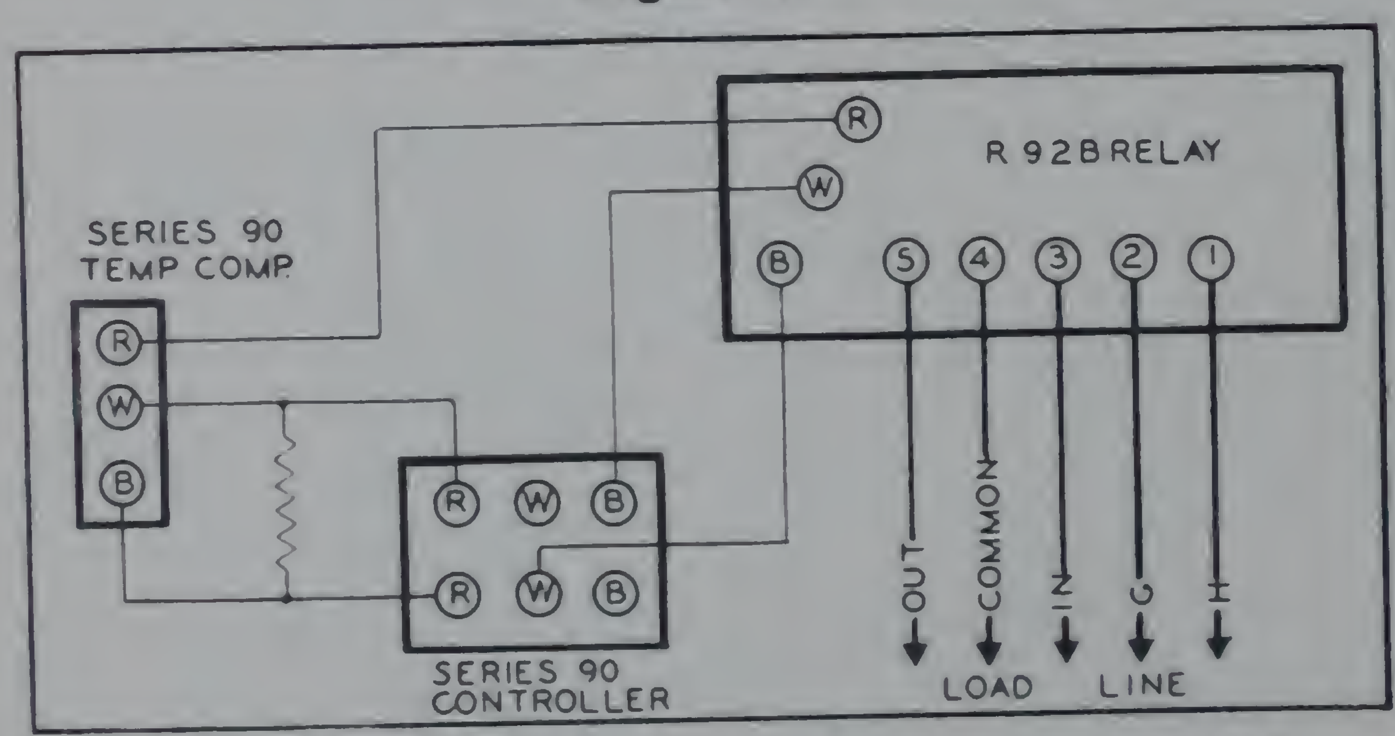


Figure 8—Connection diagram for a compensated cooling control system consisting of a R92B Relay, a single coil Series 90 compensator and a two coil Series 90 controller. The compensator should be located in the outdoor air with the controller located in either the return air duct or directly in the conditioned space. The compensator is arranged to RAISE the control point of the controller on a RISE in outdoor temperature.

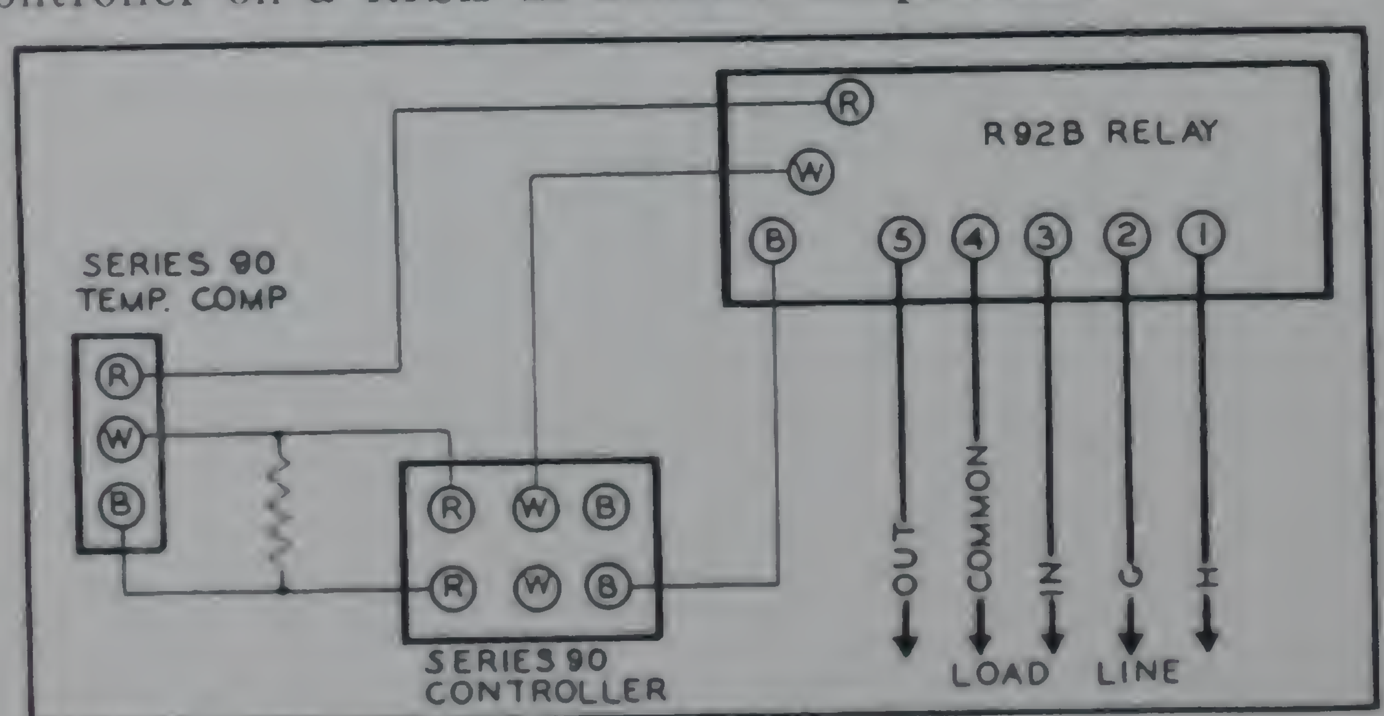


Figure 9 — Connection diagram for a compensated heating control system consisting of a R92B Relay, a single coil Series 90 compensator and a two coil Series 90 controller. The compensator should be located in the outdoor air with the controller located in a hot water boiler or similar application. The compensator is arranged to RAISE the control point of the controller on a DROP in outdoor temperature.

Averaging Control

Temperatures at two or three different locations can be measured by separate thermostats and the average of the temperatures used to position a single motor.

This system may be used with either heating or cooling equipment. The system finds its widest application in very large zones or spaces.

On an averaging control system it is necessary to use one auxiliary resistance. This resistance is placed between the B and W terminals as indicated in the following figures.

The resistance values to be used with both two and three controller installations are shown below:

No. of Controllers	Resistance Value	Part. No.
2	240	20310
3	175	20311

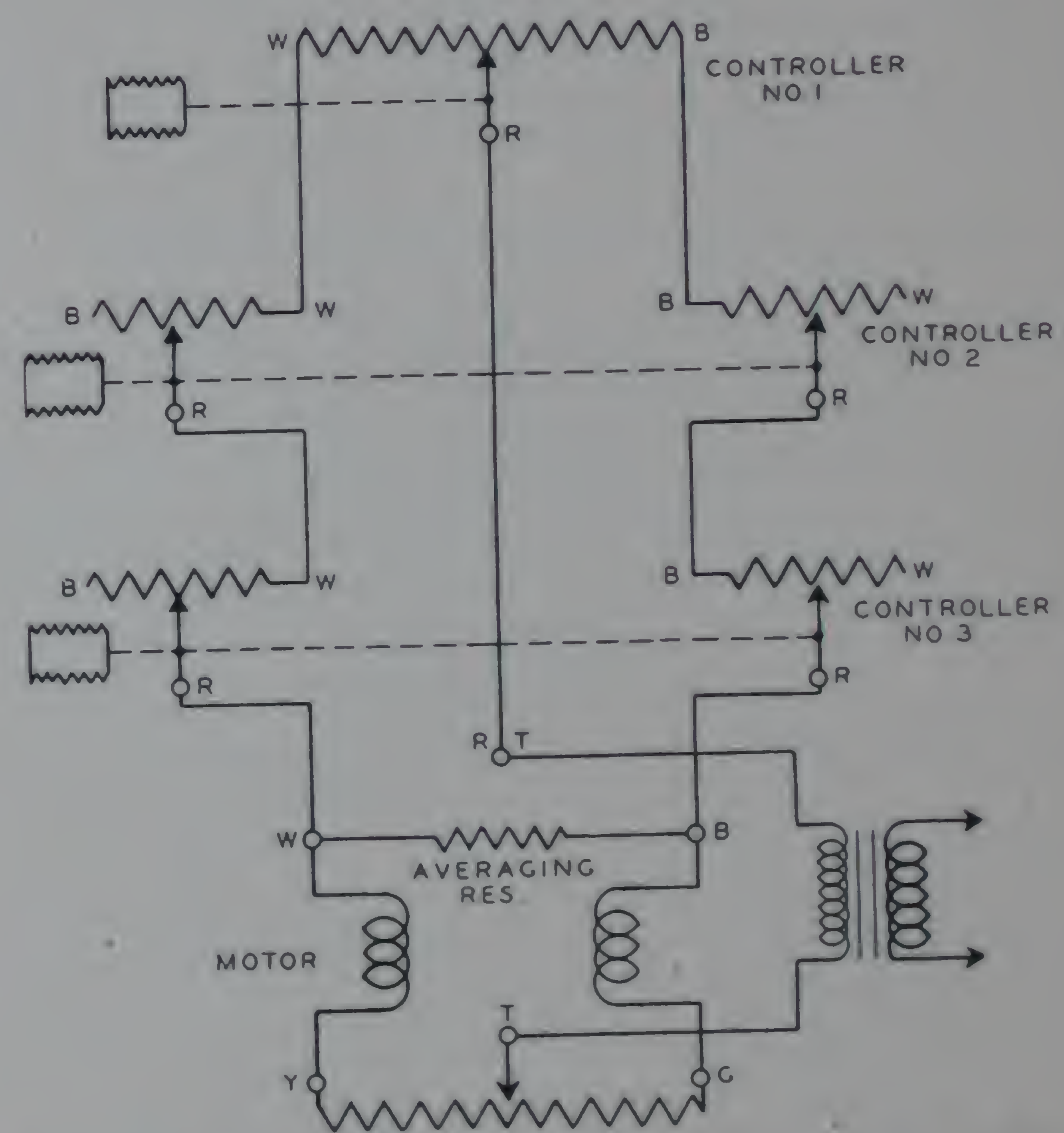


Figure 10 is a schematic wiring diagram for three averaging controllers.

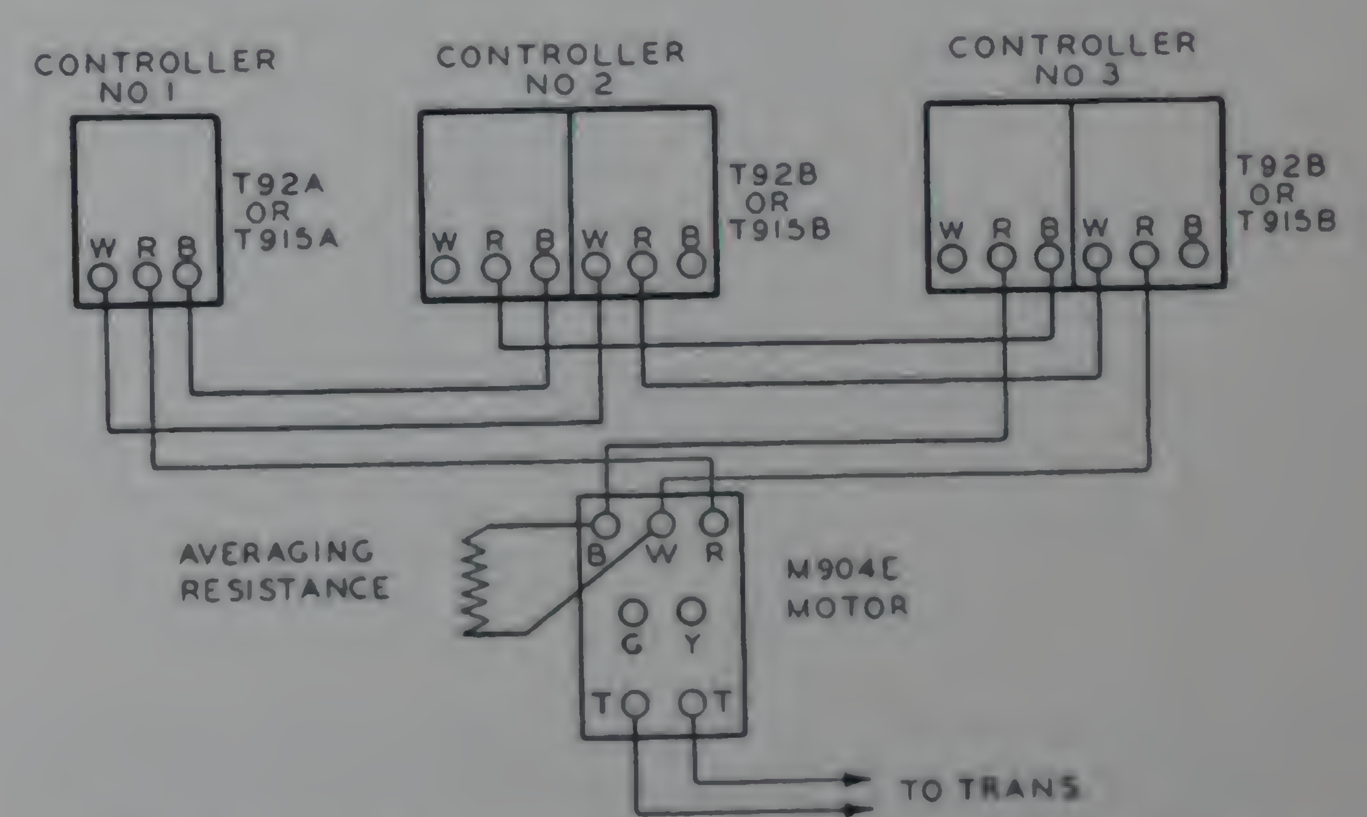


Figure 11 is a connection diagram for three averaging controllers.

PNEUMATIC CONTROL CIRCUITS

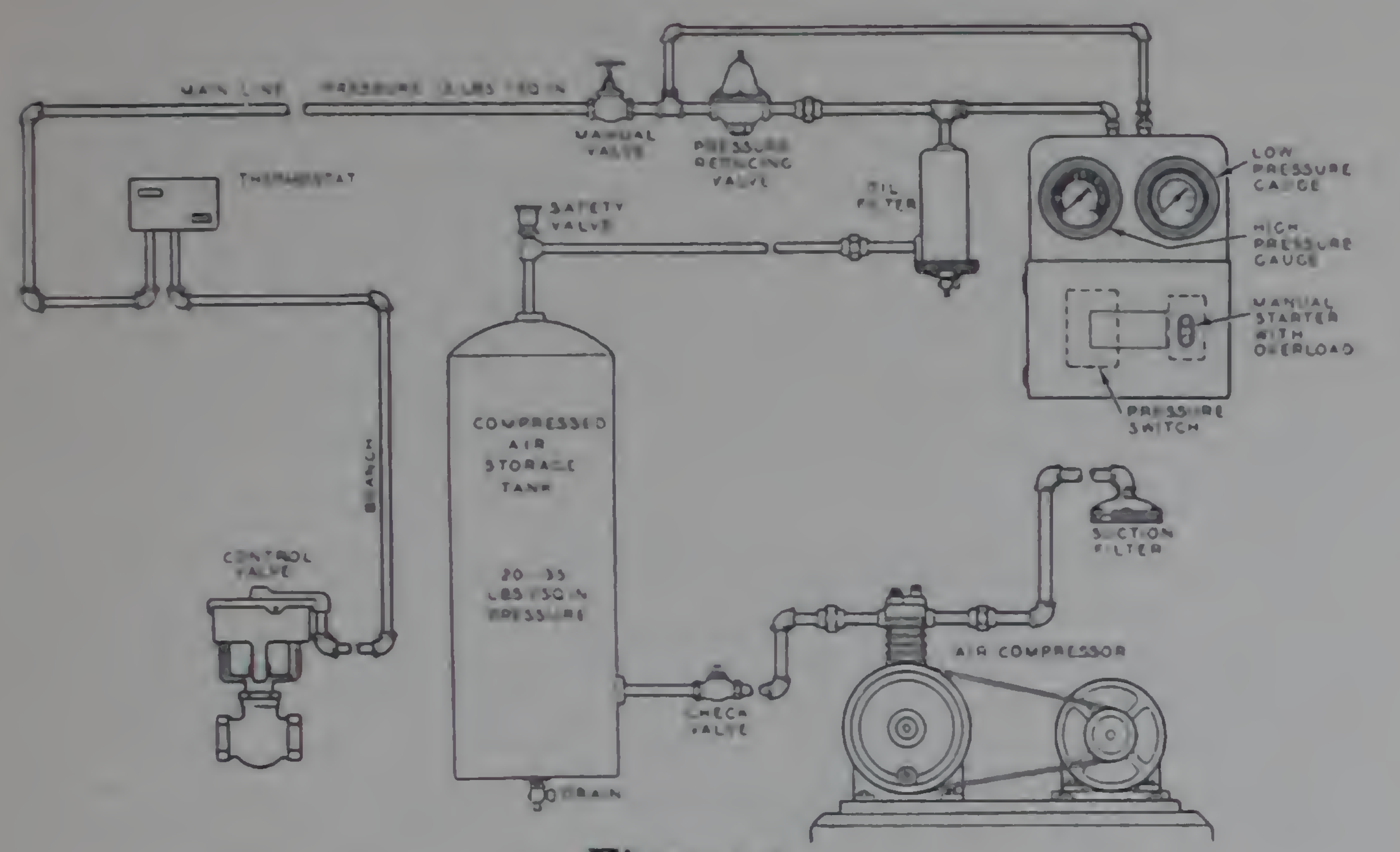


Figure 1

Figure 1 shows the elements of a typical pneumatic control system. A source of air supply is provided, usually by an electrically-driven air compressor, with which is associated a storage tank in which the air pressure is held between 20 lbs. and 35 lbs. per sq. inch. The air leaving the tank is filtered and then reduced to a pressure of 15 lbs. per sq. inch through a pressure-reducing valve. Air is delivered to all of the control devices in the system at this pressure. The control device, such as the thermostat or humidity controller, reduces the pressure in supplying air to the control valve or motor and provides a variable air pressure in the line to the motor (branch line), the pressure being varied and being determined by the demand of the thermostat or control device at that particular condition. The pneumatic control system can be divided into these parts:

1. Source of air supply.
2. Lines leading from the compressed air supply to the control devices (mains).
3. Control devices such as thermostats, humidity controllers, relays, etc.
4. Lines leading from the control devices to the controlled devices such as valves and motors (branch lines).
5. Controlled devices (valves, motors, relays, etc.)

TYPES OF PNEUMATIC CONTROLS

The function of the controller (thermostat, humidity controller, etc.) is to take air from a source of air at constant pressure (15 lbs.) and deliver it to a valve or motor at a reduced pressure. The pressure determined in the branch line by the thermostat will depend directly on the load or temperature level within the throttling range of the controller. The throttling range is defined as the temperature change at the controller that is required to change the branch line pressure from 3 to 13 pounds. Thus a thermostat with a throttling range of 3° and controlling at 72° would cause a pressure of 3 lbs. in the branch line at 70.5°. It would produce a pressure of 13 lbs. in the branch line at 73.5°, and between these limits the pressure would be proportionate to the temperature level.

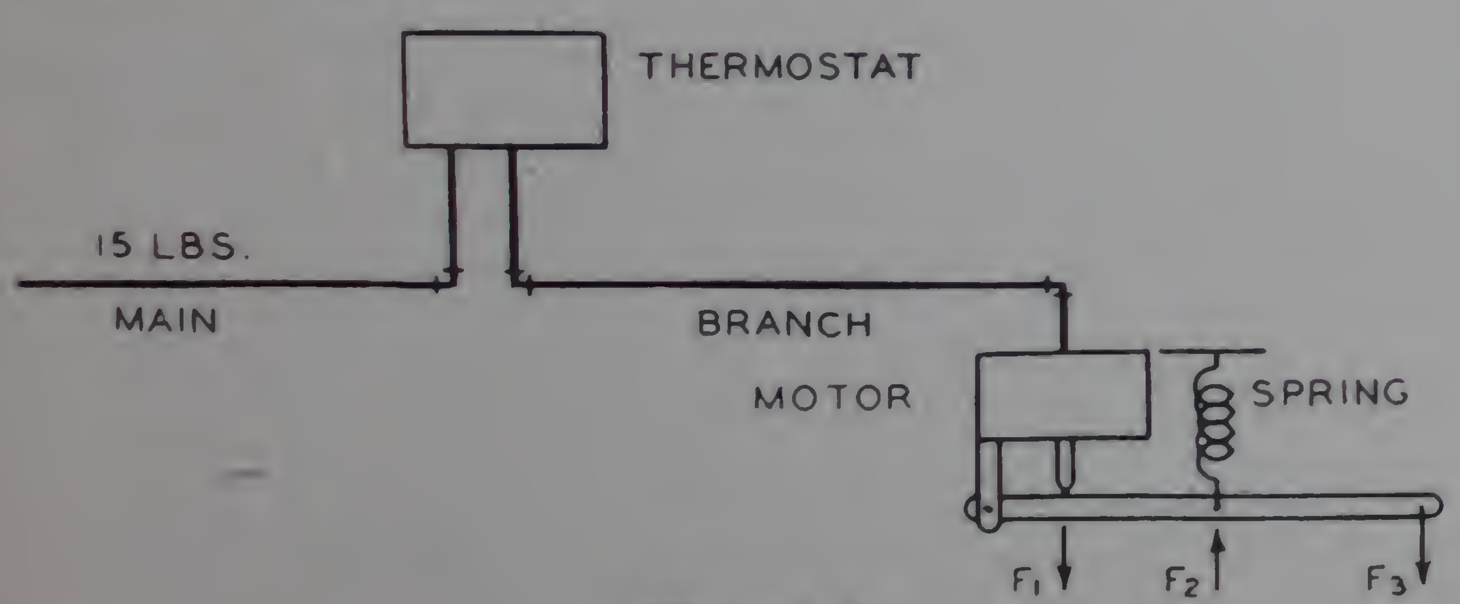


Figure 2

1. Conventional Pneumatic Control

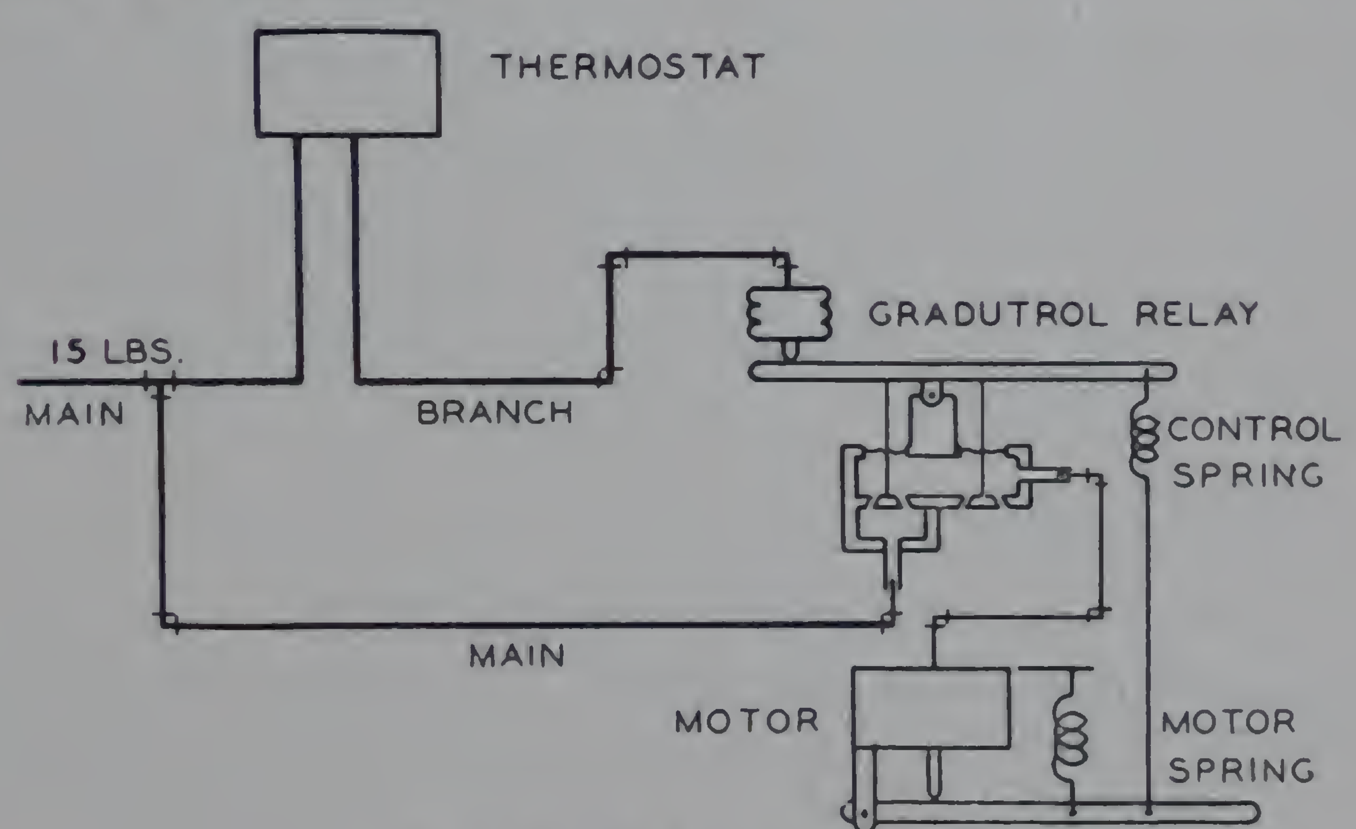
The control motor or control valve consists of a series of metal metaphrams or a composition bellows so as to respond to the pressure in the branch line. The force exerted by the control motor is balanced by a spring (see Fig. 2). Thus, the motor arm will assume a position which depends upon the balance of forces acting on the motor arm so that when a change in air pressure takes place, the motor will move until the additional spring tension again brings the motor into balance and will thereby assume a new position.

It should be noted that in the conventional pneumatic system the motor arm or valve position may not be a direct function of the branch line pressure. The position of the motor arm (or valve stem) is determined by the balance of three forces:

1. The force exerted by the motor due to the branch line pressure existing.
2. The force exerted by the spring, which is a function of the position of the arm.
3. The force exerted on the arm due to the load it is handling.

This force may be unbalanced in either direction and on such applications as outside air damper control, mav actually change from time to time depending upon wind conditions. The position of the motor for a given branch line pressure will thereby vary with the direction and intensity of the force on this arm. Where accurate positioning of large dampers is essential, this characteristic may become a serious drawback.

The load or force on the motor arm may also be due to a friction load such as would be encountered with rusty or binding dampers or on valve applications due to stuffing box friction. A friction load results in fewer control positions because the conventional pneumatic motor or valve always starts from a condition of balance where one force exactly balances the other. Thus to develop a force to offset a friction load, a rather wide change in branch line pressure is required in order to establish sufficient difference between the force exerted by the motor and that exerted by the spring to result in a movement of the motor or valve stem.



The Gradutrol System

Figure 3

2. The Gradutrol* System

Gradutrol action, sometimes called "Positive Positioning," describes a system of pneumatic control wherein the position of valves or motors depends not upon a condition of balance between the forces operating the motor, but rather depends directly upon the branch line pressure as determined by the controller. Fig. 3 shows how the Gradutrol System operates. The branch line pressure determined by the thermostat does not affect the control motor directly.

*Trade Mark

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This pressure is communicated to a diaphragm in a small relay which is equipped with two ports, one for feeding air to the motor from the main and one for bleeding air from the motor. When the relay is in balance, both ports are closed and the motor is at rest. The force exerted by the small diaphragm which is subjected to branch line pressure is balanced by a control spring which is positioned by the motor arm.

Starting from any position at rest, if the thermostat demand should change and cause even as slight an increase in branch line pressure as .1 lb., the relay will unbalance and feed air into the motor. Air will be fed to the motor until the motor arm has moved a distance sufficient to balance this change in pressure in the small diaphragm by a corresponding movement of the control spring.

It should be noted that for even this small change in pressure of .1 lb., it is possible to produce any pressure in the motor that may be required to offset the load. Thus the pressure in the motor can be anywhere from zero to 15 lbs. at any position called for by the thermostat, depending upon the amount of force required to position the motor to a definite point.

Likewise, on a decrease in branch line pressure of as little as .1 lb., the relay is again unbalanced and the port is opened which causes the bleeding of air from the motor. When the pressure in the motor has been reduced sufficiently to position the motor arm to the new position called for by the thermostat, the control spring will again come into balance with the pressure in the small diaphragm and again both ports will close with the motor in the new position which was called for by the thermostat.

The accuracy of the Gradutrol System is therefore not affected by changing loads on the damper arm or varying friction loads as in the case of the conventional system.

In the conventional pneumatic system the air pressure in the motor is the same as the air pressure in the branch thermostat line. It is thus a variable pressure depending upon the demand of the thermostat. This variable pressure established by the thermostat is balanced by the motor spring and load. Variations in this pressure require new loadings rather than new definite positions.

With the Gradutrol System a definite pressure established by the thermostat requires that the motor assume a very definite position. The motor is capable of producing full power in either direction in order to assume the position called for by the thermostat. Pressures in the motor from zero to 15 lbs. are available at all times, depending upon the force required for the motor to assume its proper position.

3. Types of Motors

Control valves are supplied in two types:

A. Normally open. A valve of this type will go to the open position on a drop in branch line pressure and will therefore remain in the open position at any time that the pressure is cut off from the system. This type of construction is normally used on radiator control applications, unit ventilators and other common applications.

B. Normally closed. This type of valve goes to the closed position on a drop in air pressure and therefore remains closed when the air is cut off from the system. This type of valve finds application on air conditioning systems, ventilating systems and places where sequence operation is desired.

The control springs used on both valves and motors normally provide for a full movement of the motor in response to a change in pressure at the thermostat from zero to 15 lbs.

The motor will normally be closed at approximately 3 lbs. and open at 13 lbs. For specialized applications it is often desirable to provide valves and motors that will operate through their full range on only a partial change in pressure at the thermostat. Thus valves and motors are available which may go from closed to open position on a change in branch line pressure of 8 to 12 lbs. or from 2 to 8 lbs., etc. Operation of this type is necessary wherever sequence control is needed, for instance, where one thermostat will control both a heating and a cooling operation.

The Gradutrol System has great advantages with respect to ease of adjustment of the operating range. With the standard Gradutrol motor the range of branch line pressure necessary to position the motor through its full range can be very readily selected and determined by very simple adjustments provided on the Gradutrol relay. This can be accomplished without changing any parts such as would be necessary in a conventional system where springs of different spring rates are needed to provide the same results.

4. Types of Thermostats and Controllers

Thermostats and controllers are available in many types designed to fit specific requirements.

a. Direct Action. A direct acting thermostat is one which causes an increase in the branch line pressure upon a rise in temperature.

b. Reverse Action. A reverse acting thermostat is one which causes a drop in branch line pressure upon a rise in temperature.

c. Graduate Action. A graduate acting thermostat is one which provides for the graduated movement of the motor or valve with the motor assuming a definite position for every condition of branch line pressure. This is the type of controller which has been discussed heretofore.

d. Positive Action. Positive action describes a thermostat or controller which does not cause graduated movement of the damper or valve but rather causes two position or "on-off" action with the valve or motor always being in one of two positions—either open or closed.

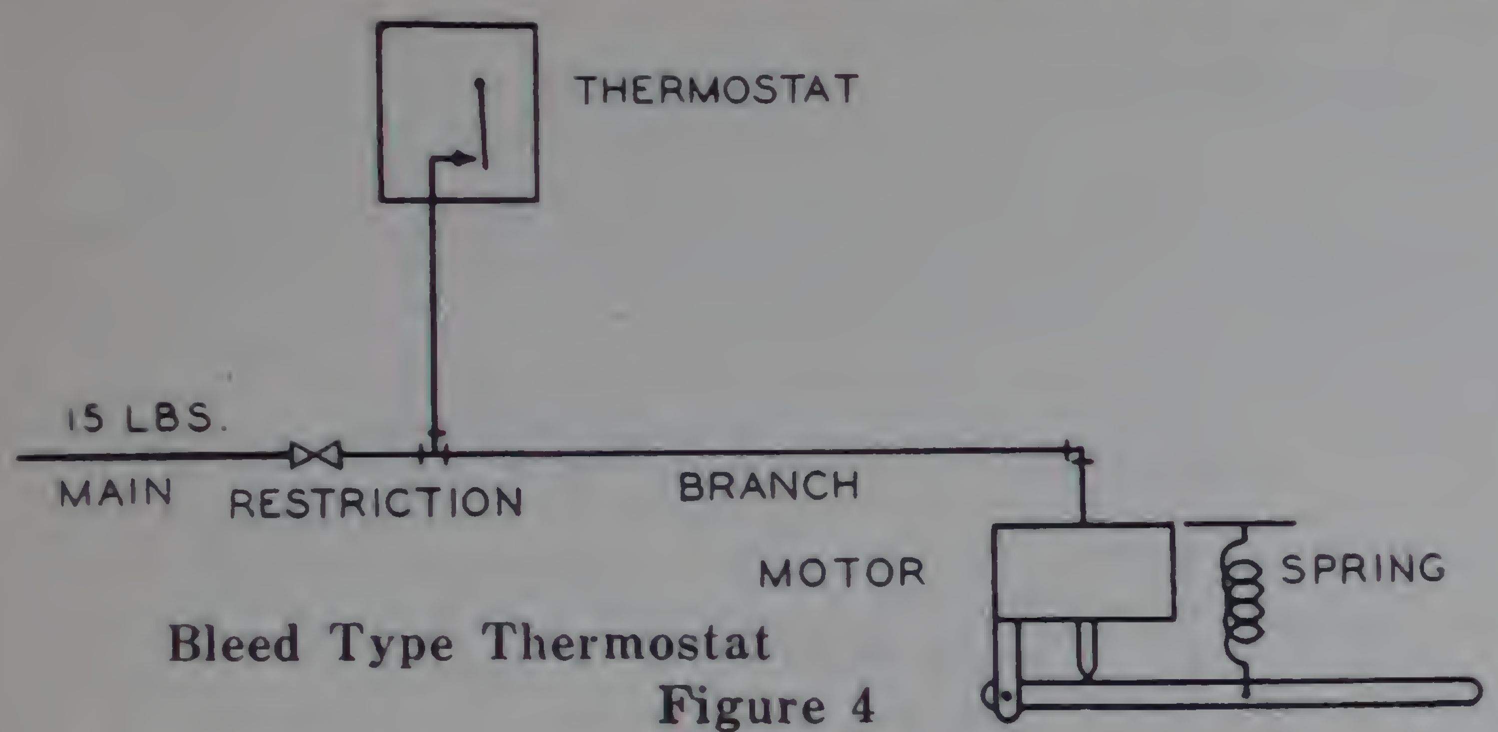
e. Other Types. There are several other types of thermostats and controllers available which will be discussed later. These include summer-winter thermostats which provide for changing the control from heating to cooling from a remote point and simultaneously re-adjusting the control point; Da-Nite* thermostats which provide for changing the control point from a day to a night level from a remote point, still permitting manual operation at the daytime level; sub-master thermostats which provide compensated control or re-adjustment of the thermostat control point from a master control which measures some other factor such as outdoor temperature.

The controller or thermostat has been described in function as being a means of regulating the branch line pressure in response to changes in temperature, pressure, or relative humidity of the medium being controlled. This is accomplished in several ways:

1. The bleed type controller (Fig. 4) This is the type of controller or thermostat which consists of a small orifice or nozzle from which the air is exhausted to the atmosphere. A restriction is provided in the main line supplying the thermostat so that air is admitted to the branch line at a fixed rate. Changes in temperature cause a vane to move toward or away from this nozzle, controlling the rate at which air is bled therefrom, which determines the pressure existing in the branch line between pressures of 15 lbs. where the vane closes the port completely and 0 lb. where the vane leaves the port free.

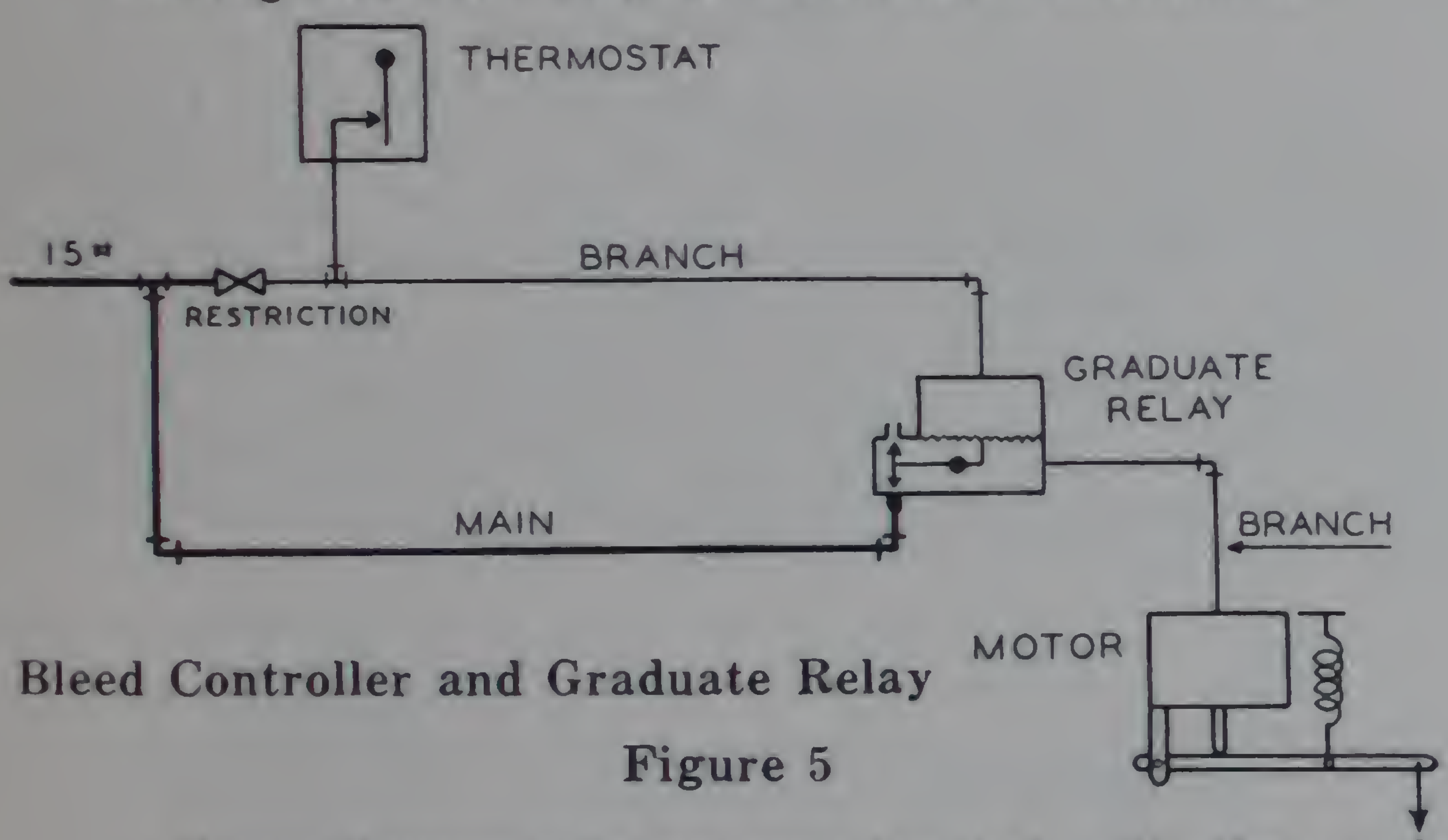
*Trade Mark

PNEUMATIC CONTROL CIRCUITS



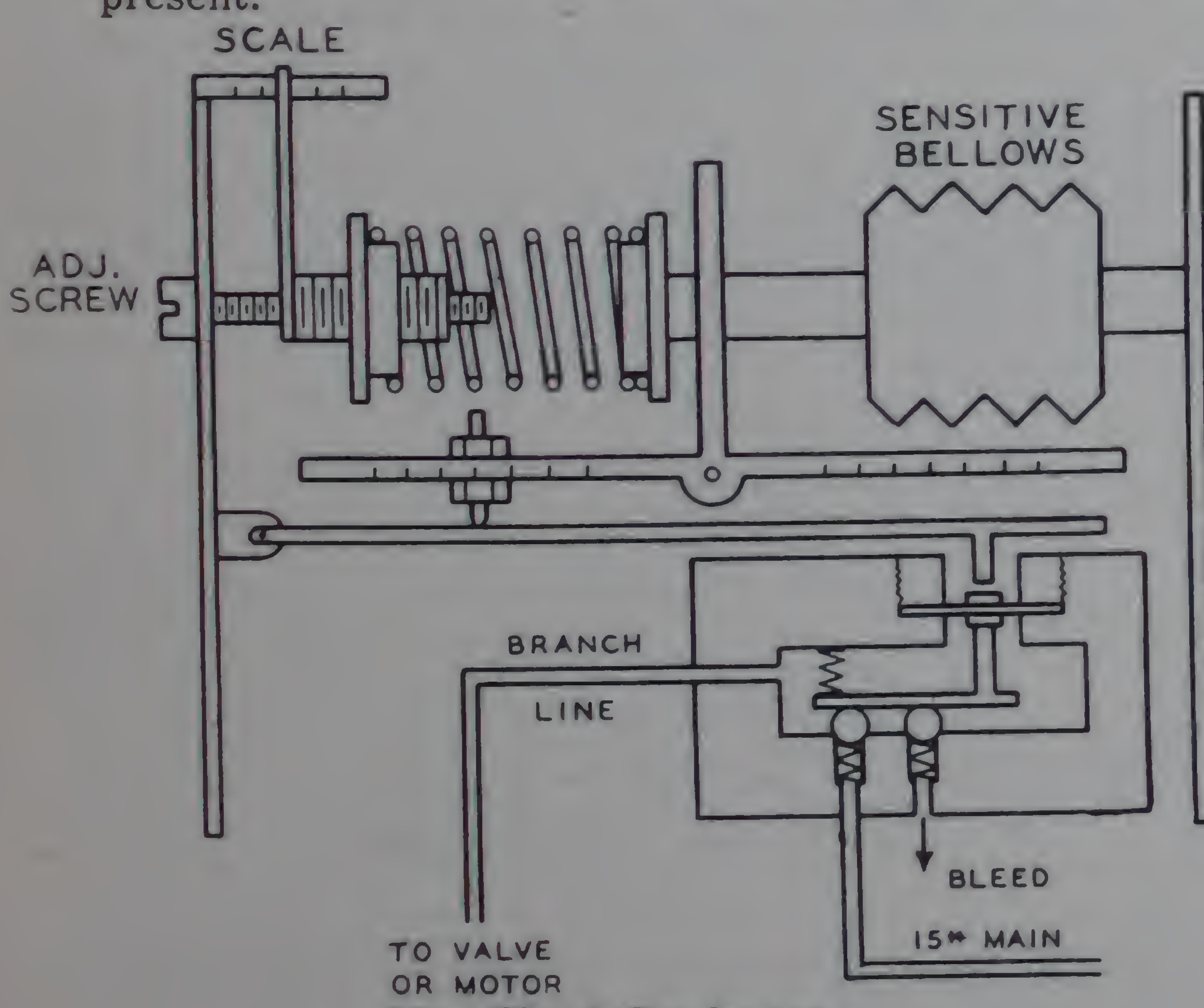
Bleed Type Thermostat
Figure 4

2. Bleed type controller with graduate relay (Fig. 5). Thermostats of this type naturally use a considerable quantity of air due to the fact that air is continually being exhausted from the system. They are therefore sometimes used with a graduate relay, the function of which is to feed and bleed air to or from the motor. Due to the fact that the amount of air required for the graduate relay is much less than that required for the valve or motor, it is possible to adjust the thermostat restriction to a smaller opening, thereby cutting down the rate at which air is exhausted.



Bleed Controller and Graduate Relay
Figure 5

Some thermostats are constructed with the graduate relay built right into the thermostat with a small bleed port then determining the pressure which the graduate relay will maintain. With a thermostat of this type, or with a combination of a bleed thermostat and separate graduate relay, air consumption is cut down but a constant bleeding of air is still present.



Non-Bleed Gradustat
Figure 6

3. Non-Bleed Controller (Fig. 6). A non-bleed controller is a type of thermostat or control that determines the branch line pressure by a pressure reducing principle which does not rely on the constant bleeding of air. Changes in temperature or other factor being controlled cause a change in control point of a small pressure reducing valve mechanism of the stop-and-bleed type. Thus air is fed to or exhausted from the system only when a change in motor position is called for. At all other times, the system is completely closed.

The Gradustat★. The Gradustat is a non-bleed type thermostat which possesses many important features. Fig. 6 illustrates the operation of the Gradustat. Changes in temperature cause a change in pressure in the temperature-sensitive bellows. This changes the loading on a small diaphragm which is exposed to the branch line pressure. In effect, a certain temperature at the thermostat establishes a control point for this small diaphragm. In order to produce the pressure in the branch line called for by the thermostat, this diaphragm can control two small ports, one of which admits air from the main to the branch line, the other of which bleeds air from the branch line. Thus following a movement of the bellows in response to a change in temperature the small port may open, admitting additional air to the branch line. When the pressure is built up to a point corresponding to the branch line pressure demanded by the thermostat, the system will again be in balance and this port will close. Likewise, should the thermostat call for a lower branch line pressure, a small port will open bleeding air from the branch line and when the motor has assumed the correct position and the branch line pressure reaches the proper point, the system will again be in balance and both ports will be closed.

The Gradustat provides many important advantages over a bleed type thermostat.

1. Air is wasted from the system only when the valve or motor is moving in one direction. At all other times the system is tight and no air is wasted. This makes possible a smaller air compressor and less operating cost.

2. The change in branch line air pressure is in direct ratio to the change in temperature, providing straight line control. This is not true of a bleed type thermostat where the relation between temperature change and branch line pressure is non-linear and takes the form of an S-curve.

3. The Gradustat provides for an adjustable throttling range. For proper control results the throttling range of the controller should be matched to the system being controlled in order to provide uniform control without hunting or wide variations in temperature. The Gradustat makes this possible due to the complete adjustment of throttling range.

4. The construction provides for a very simple change that will make the thermostat either direct or reverse acting as required. One thermostat thereby fills both requirements.

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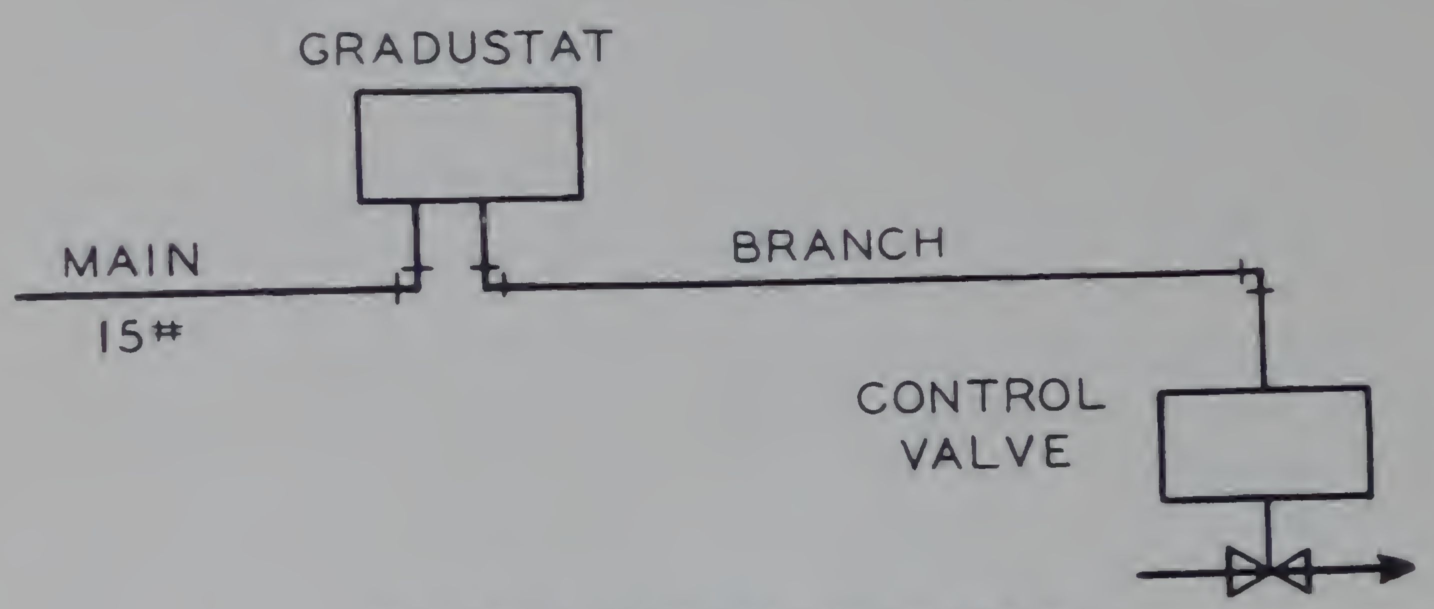
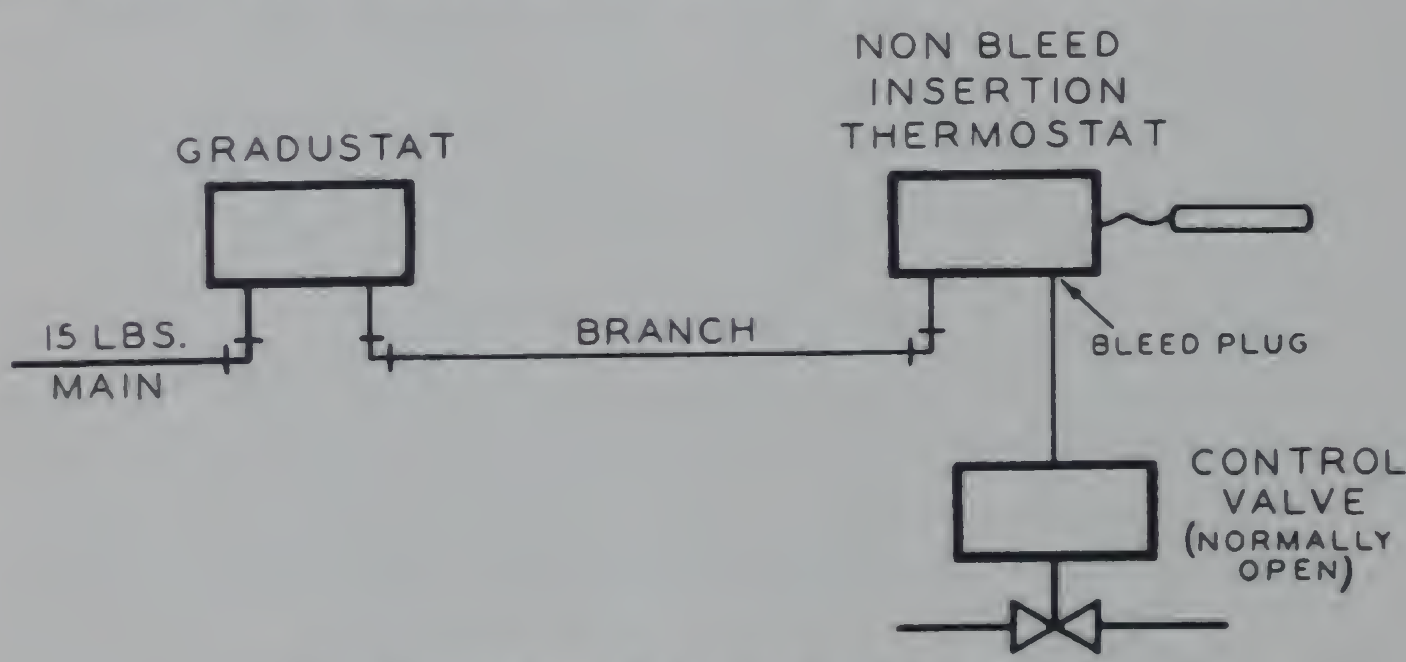
PNEUMATIC CONTROL CIRCUITS

PNEUMATIC CONTROL COMBINATIONS



Gradustat Controlling Valve
Figure 7

Frequently combinations of several controls may be desired in order to produce certain results. Fig. 7 illustrates a simple combination of a controller and control valve or motor. The controller may be set to be either direct or reverse acting and the valve can be of the normally open or normally closed type, depending upon the sequence of results desired. A direct acting thermostat and normally open control valve are most common for a heating application. For a cooling application a direct acting thermostat would be used with a normally closed control valve, or another application may be a reverse acting thermostat with a normally open control valve. Conditions of the installation and results desired will determine the combination to be used in every case.

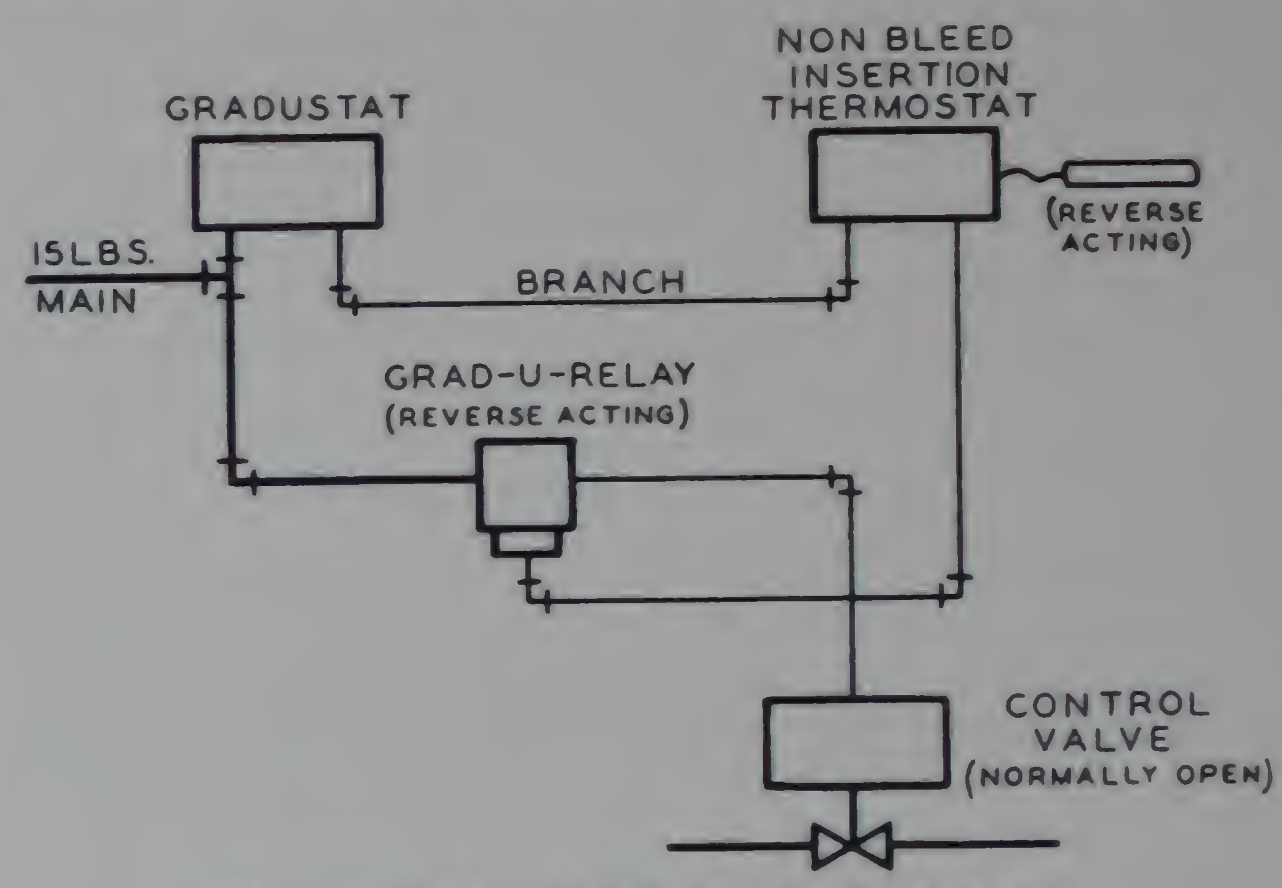


Gradustat and Low Limit Control
Figure 8

Fig. 8 illustrates the use of a limit control in a simple pneumatic control circuit. The limit control may be either high or low limit and may be used, for instance, as a discharge low limit on a blast heating system to prevent the discharge air temperature from dropping below a desired point. For a heating application the thermostat would usually be of the direct acting type and the control valve normally open. The low limit control would then be of the direct acting type and, regardless of the demands of the thermostat, will have the ability to cut down the branch line pressure, thereby opening the valve in order to prevent the discharge temperature from dropping below the desired point.

Non-bleed insertion thermostats include a small bleed plug which must be used when the units are to act as low limit controls. The bleed is located in the branch line to the valve or motor so that control will be returned to the room controller when the space temperature drops.

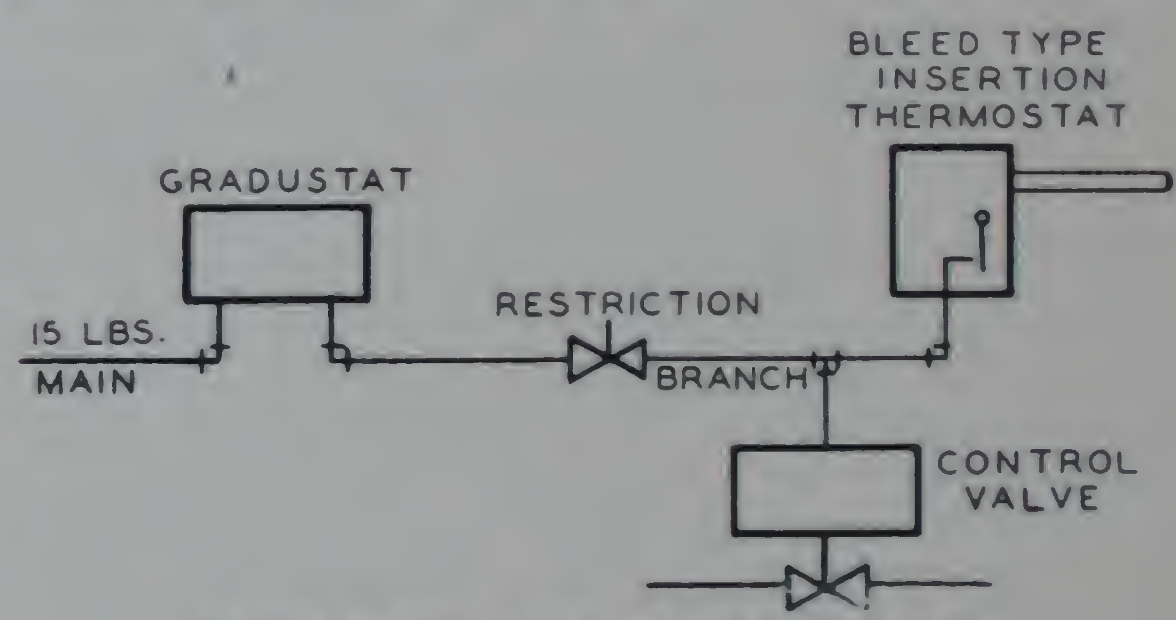
If the branch line to the valve or motor is not continuously bled it will be possible for the low limit control to take command of the valve with the room thermostat satisfied, and to position the valve so that the discharge temperature would satisfy the low limit for a long period of time. If in the meantime the space temperature should drop, so that more heat was required, it would be impossible for the room thermostat to bleed the branch line because the satisfied low limit instrument would have the branch air line stopped. By bleeding a small amount of air from the branch line a continuous flow of air will be necessary through both control instruments, and the room thermostat will always be able to open the valve.



Gradustat and High Limit Control
Figure 9

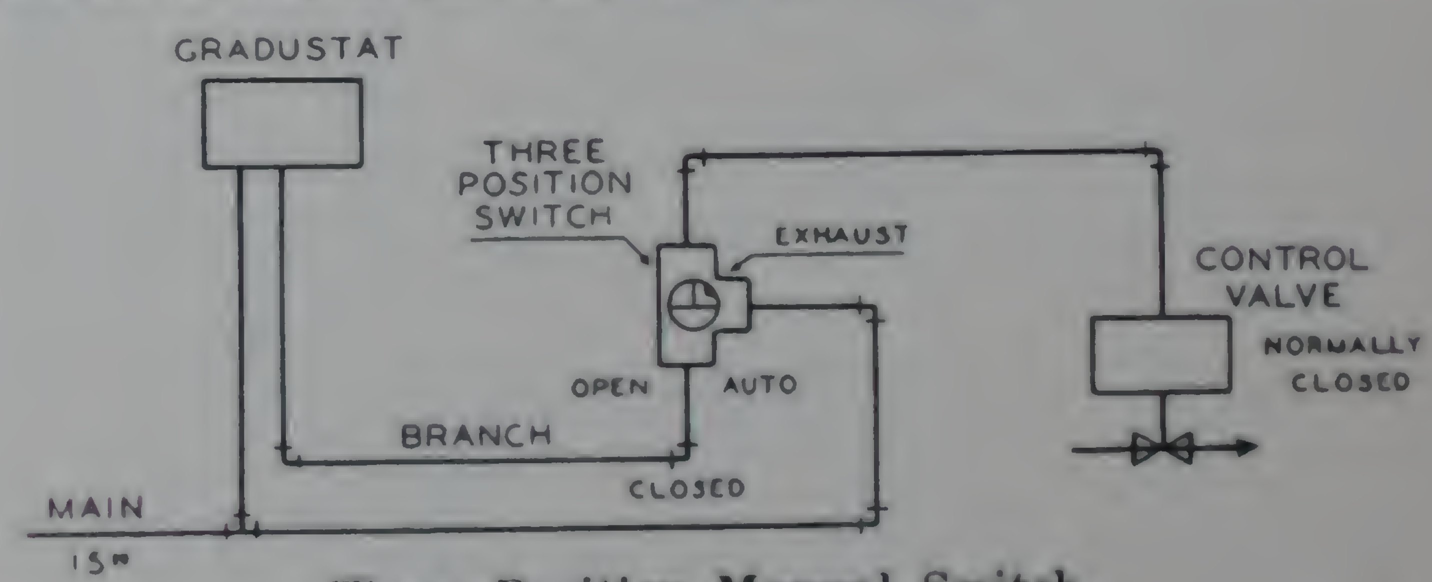
Figure 9 illustrates the most commonly used arrangement for providing high limit control. The room controller and high limit control are both set for reverse action. In order to use a normally open valve a reverse action Grad-U-Relay is inserted in the system.

A bleed in the valve branch line is necessary with high limit controls so that the room thermostat will be able to regain the control of the valve when the space temperature rises. The bleed has the same function with high limit controls as with low limit controls.



Bleed Type Low Limit Control
Figure 10

Bleed type low limit controls can be used with non-bleed controllers as shown in Figure 10. A restriction is inserted between the controller and low limit control so that the bleed type low limit will be able to completely bleed down the valve branch line and open the valve.

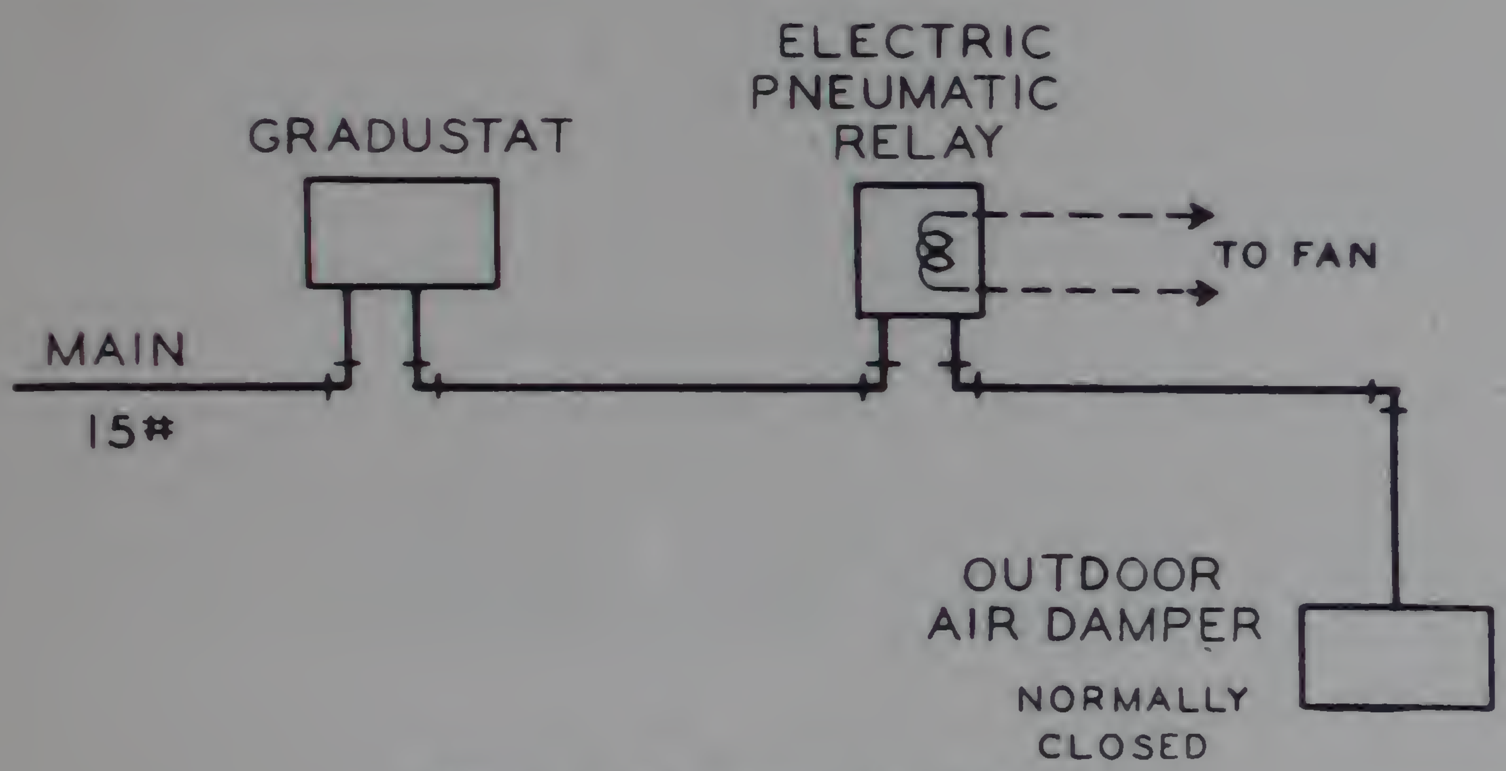


Three Position Manual Switch
Figure 11

Fig. 11 shows the use of a manual switch in connection with a pneumatic control application. This switch is used to provide manual control of a valve or motor where desired. When the switch is placed in the "automatic"

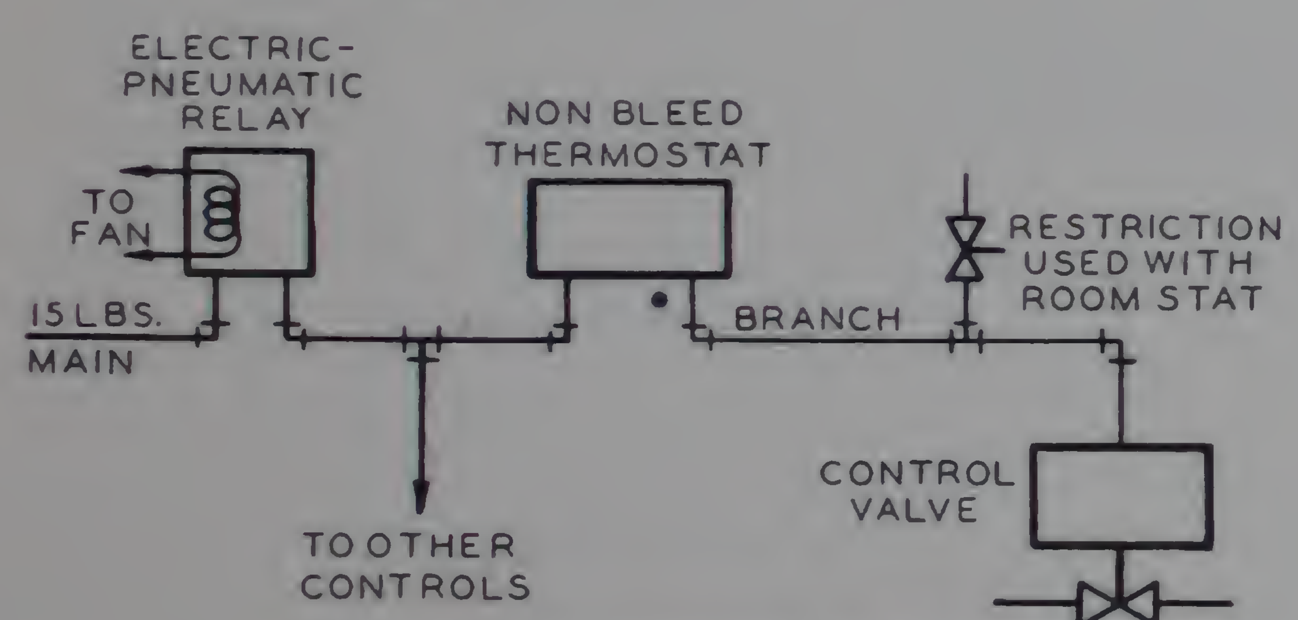
PNEUMATIC CONTROL CIRCUITS

position, the thermostat operates normally, the branch line being connected to the control motor. When the switch is placed in the "closed" position, the branch line to the thermostat is closed off and the air is bled from the motor causing the valve to close. With the switch placed in the "open" position, the branch line from the thermostat is closed and air at 15 lbs. pressure is admitted to the valve, placing it in the open position.



Electric Pneumatic Relay
Figure 12

Fig. 12 illustrates the use of an electric-pneumatic relay in a pneumatic control circuit. Frequently such a relay may be used, wired into a fan circuit so that an outside air damper can be operated to the closed position upon shutdown of the fan. The function of the relay in this case, when the fan shuts down, is to close off the branch line to the thermostat and simultaneously bleed the air from the motor so that it goes to a closed position.

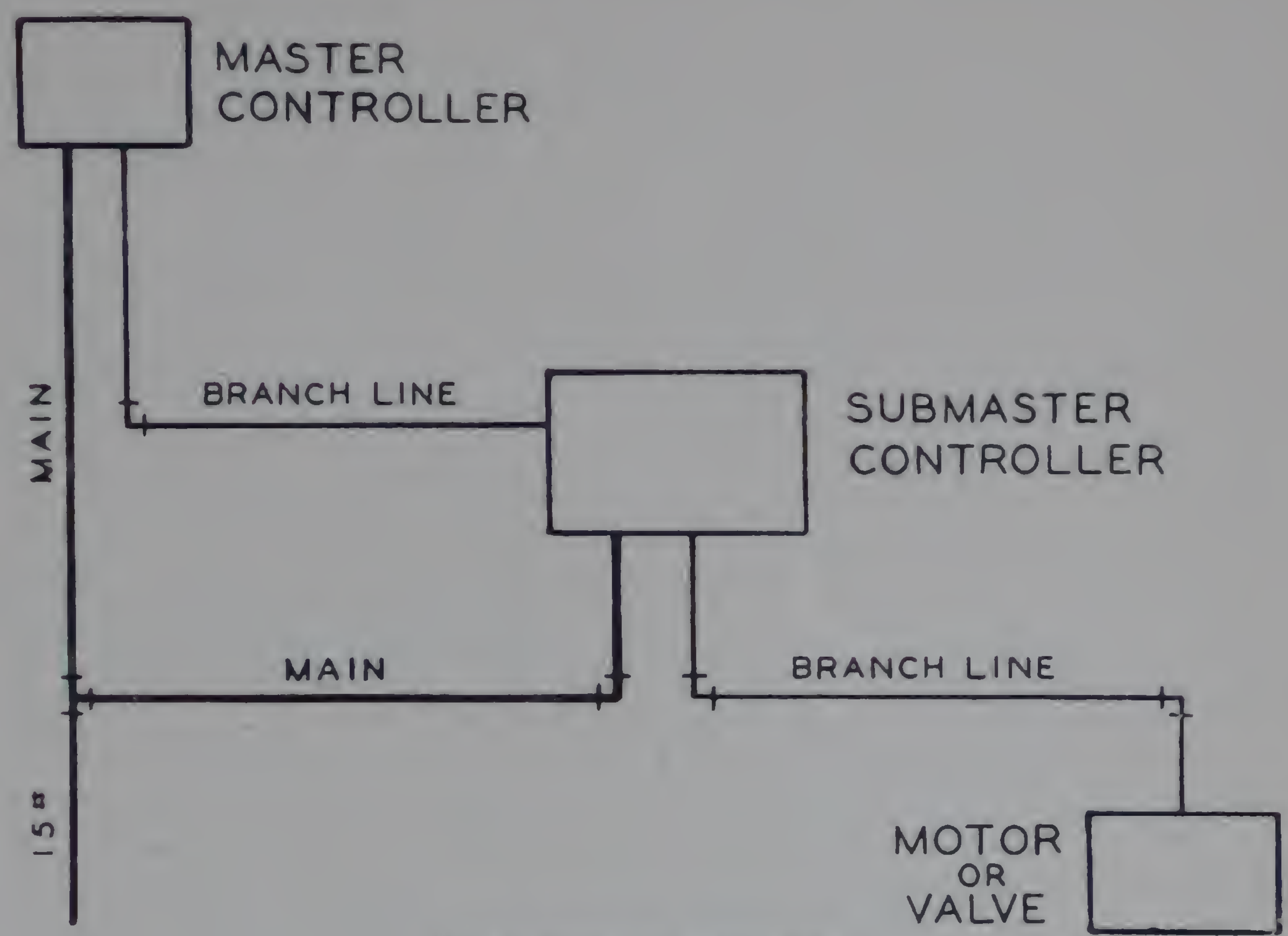


Electric Pneumatic Relay
Figure 13

When an electric-pneumatic relay is used for shutting down an entire system, it is installed as shown in Figure 13. The restriction shown in the valve line is necessary with room type Gradustats so that the motor will bleed and close immediately. The bleed plug in the insertion type instruments may be used for this purpose.

If no bleed is provided the valve or motor will not go to its normal position until the controller senses a change in temperature in the proper direction to bleed the motor line. On some systems it is necessary to have all the control equipment assume its "normal" position immediately whenever the E-P switch is de-energized.

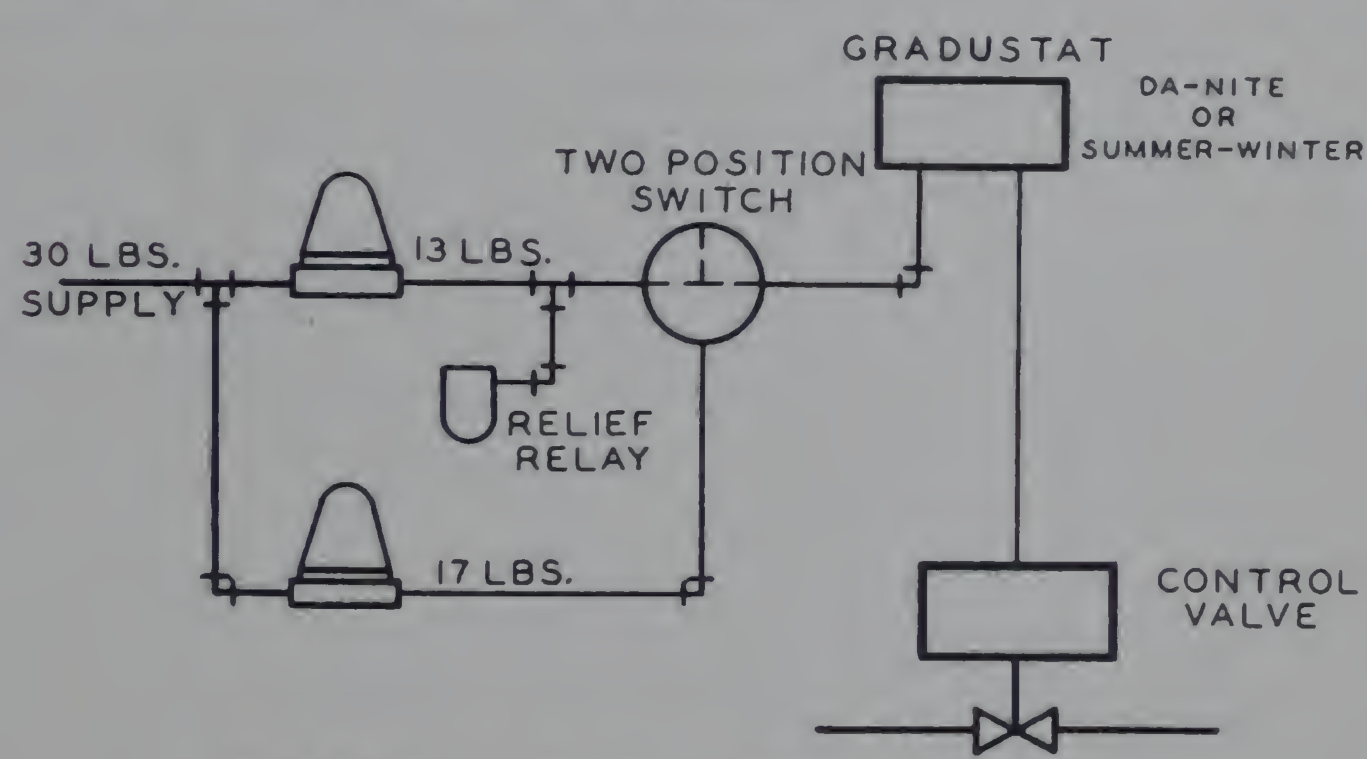
Fig. 14 illustrates a compensated, or master-sub-master, control arrangement. With this type of control one instrument (which could be, for instance, an outside master thermostat) determines the control point of a submaster control (which might be the inside thermostat in a compensated cooling control application). The master control or outside controller changes the pressure in its branch line over a wide range of outside temperatures as selected. Changes in pressure in this branch line, through



Submaster Control
Figure 14

the operation of a small diaphragm within the thermostat, change the control point of the sub-master thermostat. At any given control point, the sub-master thermostat operates normally—controlling its valve or motor.

Compensated control or master-sub-master systems are used for many applications, the most common of which is outside compensation of the inside temperature control point on cooling control systems.



Da-Nite or Summer-Winter System
Figure 15

In school buildings or on other large heating installations, lowered night temperatures are often advantageous. Through the use of Da-Nite Gradustats the changeover of all the thermostats in the building can be made either automatically or manually from a central location as illustrated in Figure 15.

Two separate pressure reducing valves one set for 13# (used during the day), and the other set for 17# (used at night), are both connected to the temperature control system through a two position switch. A change in main line pressure actuates a small relay in the thermostat which determines whether the thermostat shall control at its day or at its night temperature.

A small pressure relief relay is connected on the downstream side of the 13 pound reducing valve so that when the system switches over for day operation, the pressure in the system will immediately drop and re-establish the day control point.

A Summer-Winter Gradustat is available which can be changed over in exactly the same manner as a Da-Nite Gradustat. For Summer operation the thermostat operates at 13# and is reverse action. During the winter, 17# is used and the thermostat is direct acting. Figure 15 serves to illustrate both the Da-Nite and the Summer-Winter changeover systems.

AIR CONDITIONING

THEORY and CONTROL SYSTEMS

SECTION IV

Theory of Air Conditioning

Air-Conditioning in its broadest sense implies the control of any or all of the physical or chemical qualities of Air.

More particularly it includes the simultaneous control of:

1. **Temperature.**
2. **Humidity.**
3. **Cleaning.**
4. **Distribution.**

Since the physical properties of air vary materially from season to season it is obvious that the process of Air-Conditioning must also change on the same seasonal basis.

The functions of an Air-Conditioning System may be roughly divided as follows:

1. **Year Round functions—Cleaning and Circulating.**
2. **Heating Cycle functions—Heating and Humidifying.**
3. **Cooling Cycle functions—Cooling and dehumidifying.**

Since Automatic Control provides the only reliable and economical means of maintaining the proper relationship between these various functions, it must be considered as an inherent part of the system itself rather than an accessory or luxury.

In subsequent chapters the application of controls to various types of systems will be considered in detail, but in order to insure a complete understanding of their use it is desirable to first review the basic principles of Air-Conditioning which make them necessary.

In many instances mis-application of controls is a direct result of an incomplete analysis of the physical properties of an Air-Conditioning System in relation to the results which are desired. Occasionally controls are specified to maintain the conditioned air within limits which the conditioning equipment itself is not capable of reaching. Obviously, the control equipment can maintain conditions only within the limitation of the mechanical equipment.

A broad analysis of controls and conditioning equipment as compared with the principles governing their application will eliminate this possibility.

PURPOSE OF AIR-CONDITIONING

Applications of air-conditioning may be divided according to the conditioning of air for human comfort and the conditioning of air for the improvement of Industrial Processes.

Each of these two major classifications will be discussed separately.

1. Conditioning of Air for Human Comfort

Temperature, humidity, and air motion taken together, determine the sensation of warmth and influence the elimination of body heat. The human body, because of evaporation from its surface, behaves like a wet bulb thermometer and therefore dry air at a relatively high temperature may feel cooler than air of considerably lower temperature with a high moisture content. Air motion makes moderate conditions of the air feel cooler.

The determination of comfort conditions for any specific installation will depend largely upon the type and duration of occupancy. When these factors have been determined, the entire air conditioning system should be balanced in such a manner that the variables affecting human comfort will be maintained within proper limits.

The ability of the human body to adjust itself to marked changes in conditions will greatly influence the selection of desirable levels of temperature, humidity, and air motion. For example, in a restaurant where the period of occupancy is comparatively brief, it is found that it is impossible to maintain low temperature conditions because of the fact that an extreme sensation of shock would be felt by a person entering from an extremely warm street. This shock, of course, would be repeated upon leaving.

On the other hand, in an office building where the period of occupancy is continued for an entire day, it is possible to regulate temperatures and humidities at much lower levels.

No single comfort standard can be laid down which will meet all types of space occupancy but approximate comfort zone limits may be set up to serve merely as a general guide.

2. Conditioning of Air for the Improvement of Industrial Processes

In many industries, the temperature and relative humidity of the air have a marked influence upon the rate of production and the weight, strength, appearance, and general quality of the product. These results are due to the fact that most materials of animal or vegetable origin, and some mineral, either take up or give off moisture.

The most desirable relative humidity and temperature during processing depends upon the product and nature of the process.

SENSATIONS OF WARMTH AND COMFORT

Temperature, humidity and air motion taken together determine the feeling of warmth and influence the transference of body heat. In other words, the temperature sensations of the human body depend not only on the temperature of the surrounding air as registered by a dry-bulb thermometer, but also upon the temperature indicated by a wet-bulb thermometer. Dry air at a relatively high temperature may feel cooler than air of considerably lower temperature with a high moisture content. Air motion makes moderate conditions feel cooler.

Thermo-Equivalent Conditions

Combinations of temperature, humidity and air movement which produce the same feeling of warmth are called thermo-equivalent conditions. Elaborate experiments conducted in conjunction with the A. S. H. V. E. Research Laboratory by the Minneapolis-Honeywell Regulator Company on 275 office workers in its air conditioned offices show that this newly-developed scale of thermo-equivalent conditions not only indicate the sensation of warmth, but also determine the physiological effects on the body induced by heat and cold. For this reason, it is called the Effective Temperature scale or index.

Effective temperature is an index of warmth or cold. It is not in itself an index of comfort, as it is often assumed to be, nor are the effective temperature lines necessarily lines of equal comfort. This is true because, in determining this index, the subjects compared not the relative comfort, but rather the relative warmth or cold of various air conditions. Moist air at a comparatively low temperature, and dry air at a higher temperature may each feel as warm as air of an intermediate temperature and humidity, but the comfort experienced in the three air conditions would be quite different, although the effective temperature is the same. The intermediate condition may be entirely comfortable, but the other two would not necessarily be so.

Under extreme humidity conditions there seems to be a difference between sensations of absolute comfort and of the proper degree of warmth. In other words, human beings are not necessarily comfortable when the air is neither too warm nor too cold. Air of proper warmth may, for instance, contain excessive water vapor, and in this way interfere with the normal physiologic loss of moisture from the skin, leading to damp skin and clothing and producing more or less discomfort; or the air may be

THEORY OF AIR CONDITIONING

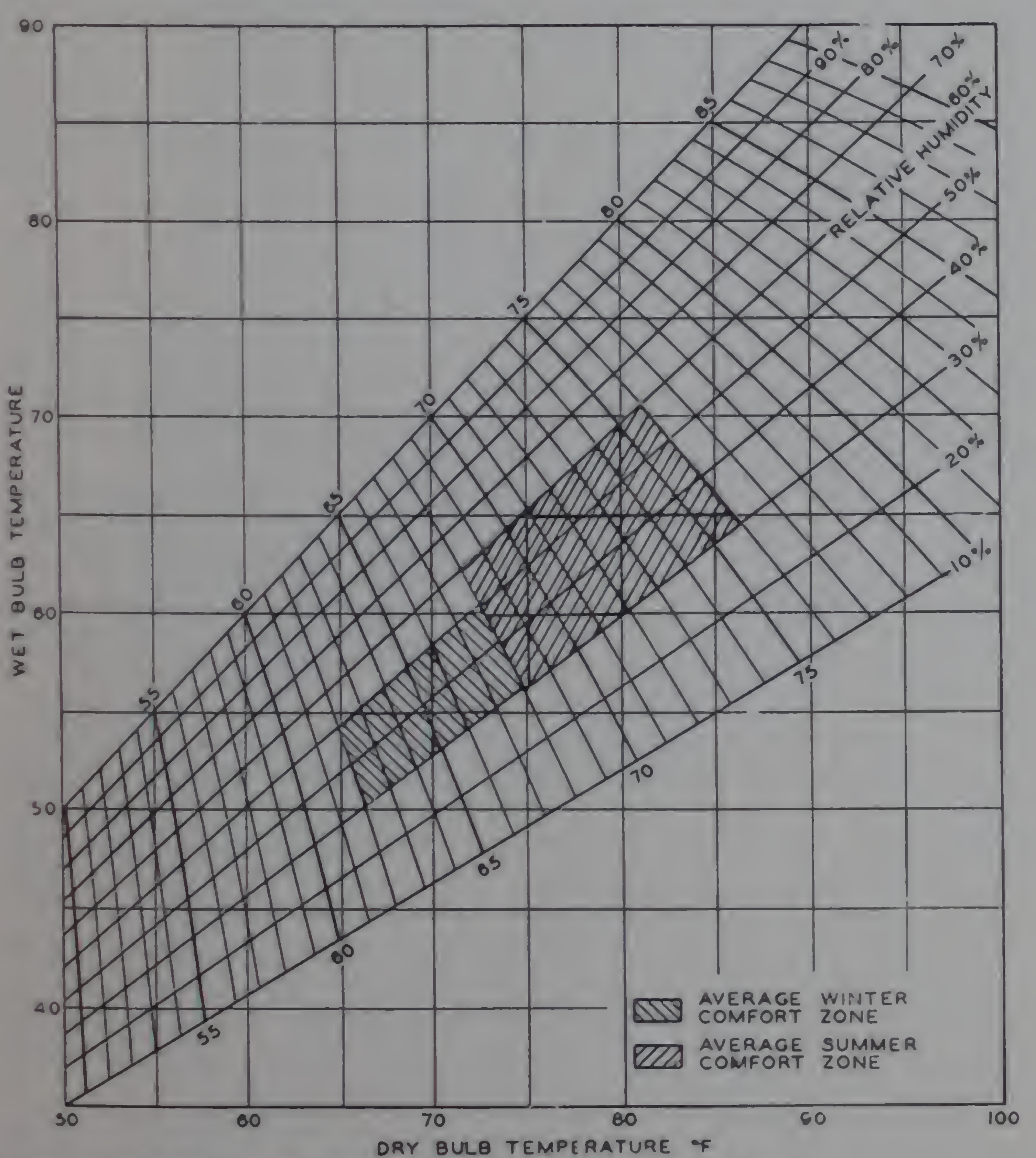
excessively dry, producing appreciable discomfort to the mucous membrane of the nose and to the skin which dries up and becomes chapped from too rapid loss of moisture. According to the comfort experiments first conducted at the A. S. H. V. E. Laboratory in the U. S. Bureau of Mines, Pittsburgh, and later studies at the Harvard School of Public Health in Boston, and the Minneapolis-Honeywell Regulator Company general offices in Minneapolis, effective temperature appears to be a fair index of comfort also, but only within a humidity range of 30 to 60 per cent, approximately.

Definition of Effective Temperature

Briefly, effective temperature may be defined as an arbitrary index of the degree of warmth or cold felt by the human body in response to temperature, humidity, and movement of the air. Effective temperature is not a temperature at all; it is a composite index which combines the readings of temperature, humidity and air motion in a single value. The numerical value of the effective temperature index for any given air condition is fixed by the temperature of saturated air which, at a velocity or turbulence of 15 to 25 fpm, induces a sensation of warmth or cold like that of the given condition. Thus, an air condition has an effective temperature of 65 deg. when it induces a sensation of warmth like that experienced in practically still air at 65° F. saturated with moisture.

OPTIMUM AIR CONDITIONS

No single comfort standard can be laid down which would meet every need. There is an inherent individual variation in the sensation of warmth or comfort felt by persons when exposed to an identical atmospheric condition. The state of health, age, sex, clothing, activity, and the degree of acquired adaptation seem to be the important factors affecting the comfort standards.



Comfort Chart; Comfort Line; Comfort Zone

Above is shown a comfort chart, developed at the A. S. H V. E. Laboratory on which the average and extreme comfort zones have been superimposed. The extreme comfort zone includes air conditions in which one or more of the experimental subjects were comfortable. The average comfort zone includes those air conditions in which the majority of the subjects (50 per cent or more) were comfortable. That particular effective temperature at which the maximum number of subjects was comfortable was called the comfort line.

The average winter comfort zone as determined at the A. S. H. V. E. Laboratory ranges from 63 deg. to 71 deg. ET (effective temperature), 97 per cent of the experimental subjects were found to be comfortable at 66 deg. ET while at rest, and this temperature was accepted as the winter comfort line or optimum effective temperature.

The comfort line separates the cool air conditions to its left from the warm air conditions to its right. Under the air conditions existing along or defined by the comfort line, the body is able to maintain thermal equilibrium with its environment with the least conscious sensation to the individual, or with the minimum physiologic demand on the heat regulating mechanism. This environment involves not only the condition of the air with respect to temperature and humidity, but also the condition of the surrounding objects and wall surfaces. The comfort zone tests were made in rooms with wall surface temperatures approximately the same as the room dry-bulb temperature. For walls of large area having unusually low surface temperatures, however, a somewhat higher range of effective temperature is required to compensate for the increased loss of heat from the body by radiation.

The average summer comfort zone for exposures of 3 hours or more ranges from about 66 deg. to 75 deg. ET, based on studies made at the Harvard School of Public Health. The probable optimum effective temperature (for exposures of 3 hours or more) is 71 deg. These effective temperatures average about 4 deg. higher than those found in winter when customary winter clothing was worn. The variation from winter to summer is probably due partly to adaptation to seasonal weather and partly to differences in the clothing worn in the two seasons.

The best effective temperature (for exposures lasting 3 hours or more) was found to follow the average monthly outdoor temperature more closely than the prevailing outdoor temperature. It remained at approximately the same value in July, August and September, and although the average monthly temperature did not vary much, the prevailing outdoor temperature ranged from 70° F. to 99.5° F. A decrease in the optimum temperature became apparent only when the prevailing outdoor temperature fell to 66° F. which is below the customary room temperature in the United States for summer and winter.

APPLICATION OF COMFORT CHART

The average winter comfort line (66 deg. ET) applies to average American men and women living inside the broad geographic belt across the United States in which central heating of the convection type is generally used during four to eight months of the year. It does not apply to rooms heated by radiant energy, and has not been advocated officially for use in foreign countries where the climate, heating methods, and general living conditions are materially different from those in the United States, although several foreign workers have attempted to show that it cannot be so applied. Even in the warm south and southwestern climates, and in the very cold north-central climate of the United States, the comfort chart would probably have to be modified according to climate, living and working conditions, and the degree of acquired adaptation.

In densely occupied spaces, such as classrooms, theatres and auditoriums, somewhat lower temperatures are necessary than those indicated by the comfort line on account of counter radiation between the bodies of occupants in close proximity. In rooms in which the average wall surface temperature is considerably below the air temperature, higher air temperatures are necessary. The reverse holds true in radiant or panel heating methods.

THEORY OF AIR CONDITIONING

The sensation of comfort, insofar as the physical environment is concerned, is not absolute but varies considerably among certain individuals. Therefore, in applying the air conditions indicated by the comfort line, it should not be expected that all the occupants of a room will feel perfectly comfortable. When the winter comfort line is applied in accordance with the foregoing recommendations, the majority of the occupants will be perfectly comfortable, but there will always be a few who will feel a bit too cool and a few a bit too warm.

Air conditions lying outside the average comfort zone but within the extreme comfort zone may be comfortable to certain persons. In other words, it is possible for half of the occupants of a room to be comfortable in air conditions outside the average comfort zone, but in the majority of cases, if not in all, these conditions will be well within the extreme comfort zone as determined experimentally.

The summer comfort line (71 deg. ET) is applicable to the same geographic area as the winter comfort line. It is further restricted to cases in which the human body has reached thermal equilibrium with its environment. As a general rule this takes place after 1½ to 3 hours exposure. When a person from outdoors enters a room cooled to 71 deg. ET on a hot day (95° F. or over) an intense chill is likely to be experienced which is unpleasant. However, after remaining in the room for about 2 hours, this fundamental optimum condition will prove satisfactory to the average person. The summer comfort zone, as well as the comfort line, makes proper allowance for these adaptive changes in the body, and thus applies to homes, offices, schools and other similar places where persons of sedentary occupations spend from 3 to 8 or more hours daily.

In artificially cooled theatres, department stores, restaurants, and other public buildings where the period of occupancy is short, the contrast between outdoor and indoor air conditions becomes the deciding factor in regard to the temperature and humidity to be maintained. The object of cooling such places in the summer is not to reduce the temperature to the optimum degree, but to maintain therein a temperature which is temporarily comfortable to the patrons who thus avoid sensations of chill and intense heat on entering and leaving the building. The relative humidity should be low enough (about 50 per cent or less) to give a sense of comfort without chill and to induce a rate of evaporation which will keep clothing and skin dry. For exposures less than 3 hours, desirable indoor conditions in summer corresponding to various outdoor temperatures are given in Table 1.

TABLE 1. DESIRABLE INDOOR AIR CONDITIONS IN SUMMER TO OUTDOOR TEMPERATURES

Applicable to Exposure Less Than 3 Hours

Outdoor Temp. (Deg. Fahr.)	Indoor Air Conditions with Dew-Point Constant at 57° F.
Dry-Bulb	Effective Temp.
100	74
95	73
90	72
85	71
80	70
75	69
70	68

DEFINITIONS OF AIR-CONDITIONING TERMS

Since any discussion of the application of automatic controls must necessarily include certain air-conditioning terms, it is believed that the inclusion of definitions of several of these terms common to air-conditioning will be advantageous.

1. Dry Bulb Temperature

The dry bulb temperature of the air is the temperature indicated by any type of thermometer not affected by the water vapor content of the air.

2. Wet Bulb Temperature

The wet bulb temperature is determined by a thermometer with a bulb encased in a fine mesh fabric bag moistened with clean water and whirled through the air until the thermometer assumes a steady temperature. The wet bulb thermometer measures the equilibrium temperature of water evaporating into air when the latent heat of vaporization is supplied by the sensible heat of the air.

3. Dew Point Temperature

If a mixture of dry air and water vapor, initially unsaturated, be cooled at constant pressure, the temperature at which condensation of the water vapor begins within the main body is called the dew point temperature.

4. Relative Humidity

The ratio of the existing vapor pressure in air at a given dry bulb and wet bulb condition to the vapor pressure when saturated at the same dry bulb temperature is called the relative humidity of the air.

5. Latent Heat

The heat necessary to change a unit quantity of water into steam at constant pressure is called latent heat.

6. Sensible Heat

Sensible heat is the heat which may be determined by a dry bulb thermometer. Changes in sensible heat will change thermometer readings.

7. Total Heat

The sum of the sensible and latent heat of moisture is equal to the total heat and may be measured by a wet-bulb thermometer.

PSYCHROMETRIC CHART

Description of the Chart

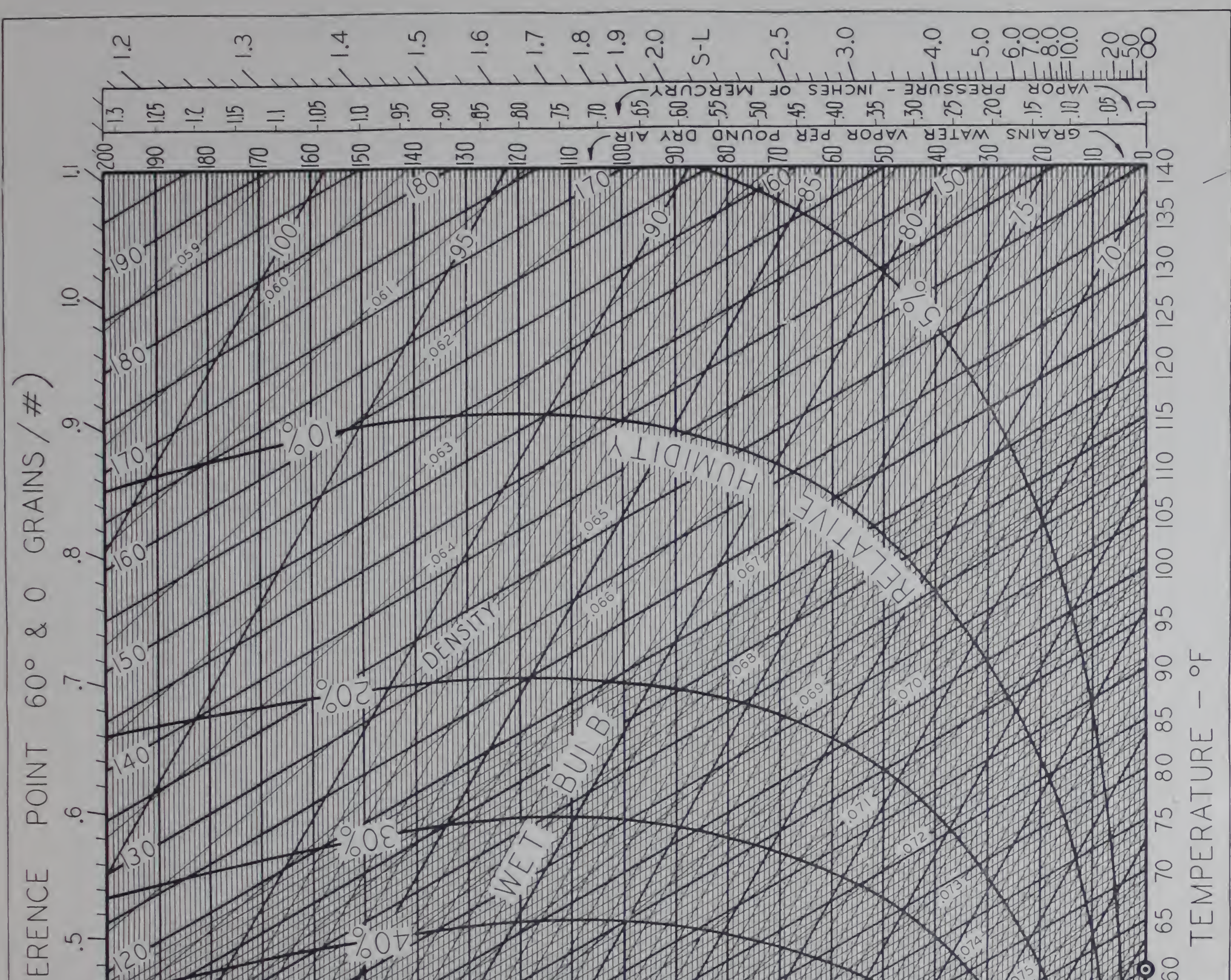
The chart offers an easy means of graphically illustrating the change in the physical properties of Air as it passes through an Air-Conditioning system and serves its function of offsetting heating or cooling loads.

The chart is frequently considered merely as a means of determining the functions of heat exchange within the conditioning unit itself. This interpretation is only partially correct since the physical heat transfer between air discharged from the unit and the air within the conditioned space may be carefully analyzed by use of the chart.

This heat transfer within the conditioned space is the basic principle around which air-conditioning systems must be designed. The conditioning equipment itself provides only a means whereby the discharge air may be maintained at a level which will insure the proper type and amount of heat exchange within the space.

Given any limits of operating conditions for an Air-Conditioning System it is possible to use the chart to determine the limits of possible results. Thus it is possible to determine with accuracy the Automatic Controls which are best suited to insure those results.

One form of Psychrometric chart is illustrated in detail on page 5, and in skeleton form in Fig. 1. Since the chart is only a graphical means of representing the relationship between the properties of air it is possible to vary its arrangement without effecting its value. The chart as illustrated is only one of several types available. While the means of determining values on this chart will not be applicable to all types the values themselves may be interpreted similarly.


PSYCHROMETRIC CHART
29.921 BAROMETER
MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
MPLS. MINN.
SENSIBLE - LATENT RATIO — (REFERENCE POINT 60° & 0 GRAINS/#)
DRY BULB TEMPERATURE - °F
GRAINS WATER VAPOR PER POUND DRY AIR
VAPOR PRESSURE - INCHES OF MERCURY
RELATIVE HUMIDITY
WET BULB
DENSITY
B.T.U./# DRY AIR CORRESPONDING TO W.B.
SILICA GEL
ADIABATIC DRYING
S-L

THEORY OF AIR CONDITIONING

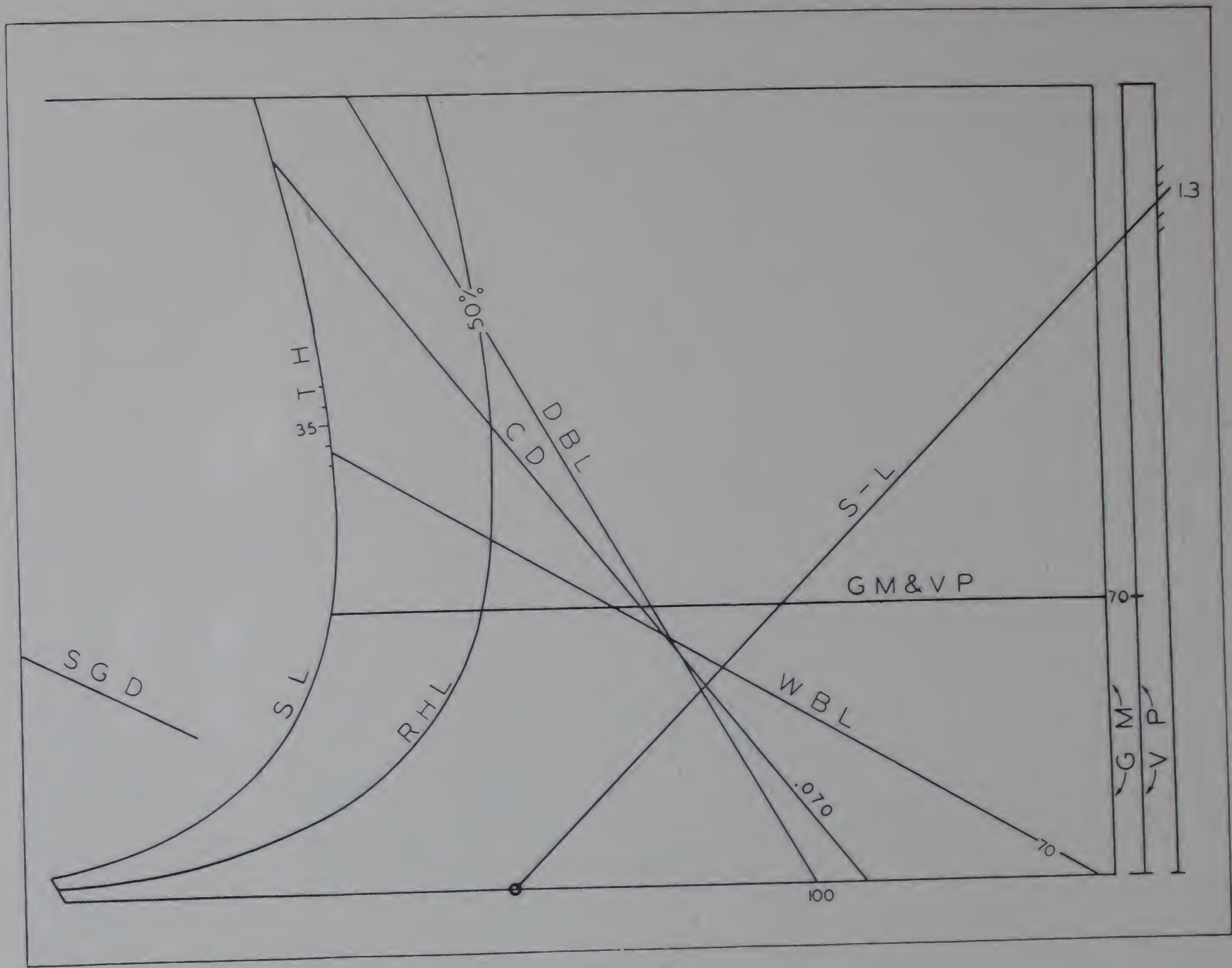


Figure 1

DESCRIPTION OF THE PSYCHROMETRIC CHART

This chart is so designed that the ordinary air-conditioning processes may be represented by straight lines. Following the customary procedure, all values given are based on an air quantity of 1 lb. of dry air. The two main scales of the chart are the dry bulb scale shown at the bottom of the chart and the scale entitled "Grains of Water Vapor per lb. of Dry Air" at the right hand margin of the chart. The lines of constant dry bulb temperature slope upward and to the left from the lower scale, and the saturation line is the curved line at the left of the chart. Lines of constant relative humidity are the curved family of lines running somewhat parallel to the saturation line. All horizontal lines running to the right from the saturation line are lines of constant moisture content, constant dew point and constant vapor pressure. The vapor pressure is read in inches of mercury on the vapor pressure scale. Between the dry bulb and the horizontal lines is another family of slanting lines labeled "Wet Bulb" lines. The intersections of the wet bulb lines or the dry bulb lines with the saturation curve also represent corresponding dew point temperatures. Superimposed on these systems of lines is another series representing constant density of the air and water vapor mixtures. Around the periphery of the chart is a scale showing the slope of the sensible to latent ratios involved in changing the condition of the air from one point on the chart to any other point on the chart. The reference point for the use of this scale is the circled dot which will be noted at the intersection of the zero grains per lb. line and the 60 degree dry bulb temperature line. Fig. 1 shows a skeleton psychrometric chart which illustrates the various lines referred to in the discussions. These lines are as follows:

DBL—Dry Bulb Line
RHL—Relative Humidity Line
WBL—Wet Bulb Line
SL—Saturation Line
GM—Grains of Moisture per lb. of dry air

TH—Total Heat scale
VP—Vapor Pressure in inches of mercury
CD—Constant Density
S-L—Sensible to Latent heat ratio
SGD—Silica Gel Drying

THEORY OF AIR CONDITIONING

EXAMPLES IN THE USE OF THE PSYCHROMETRIC CHART

The Psychrometric chart may be used to make two separate types of determinations:

1. **The values of the various properties of air under a fixed set of conditions.**
2. **The change in values of the various properties of air under a changing set of conditions.**

I. Properties of Air Under Fixed Conditions

In testing an Air-Conditioning System a sling psychrometer is used to determine that the dry bulb temperature is 80° F. and the wet bulb temperature is 67° F.

a. **Question: What is the relative Humidity?**

Solution: Referring to Fig. 2 a line is drawn downward to the right along the 67° "Wet Bulb" line to intersect the 80° dry bulb line at point "A". The relative humidity is read directly on the family of "Relative Humidity" curves and is found to be fifty per cent.

b. **Question: What is the dew point?**

Solution: From point "A" a horizontal line is drawn to the left until it intersects the saturation curve at "B"—the dew point is then read directly from this curve and is found to be sixty and one-half degrees F.

c. **Question: What is the Vapor Pressure?**

Solution: From point "A" a horizontal line is drawn to the right until it intersects the scale labeled "Vapor Pressure in inches of water" at "C". The vapor pressure is read directly from this scale and is found to be .53 inches of Mercury.

d. **Question: How many grains of Moisture are there in each pound of Air?**

Solution: Note the point of intersection at point "D" of the line drawn from "A" in the previous solution with the first scale on the right hand side of the chart. The grains of moisture per pound of air is read directly from this chart and is found to be seventy-eight grains per pound.

e. **Question: What is the total heat above zero degrees in B.T.U. per lb. of dry air?**

Solution: Follow the 67° wet bulb line from point "A" until it intersects the saturation curve at "E". Read on the scale marked "B.T.U. per lb. of dry air corresponding to W.B." The total heat is then found to be 31.2 B.T.U. per lb.

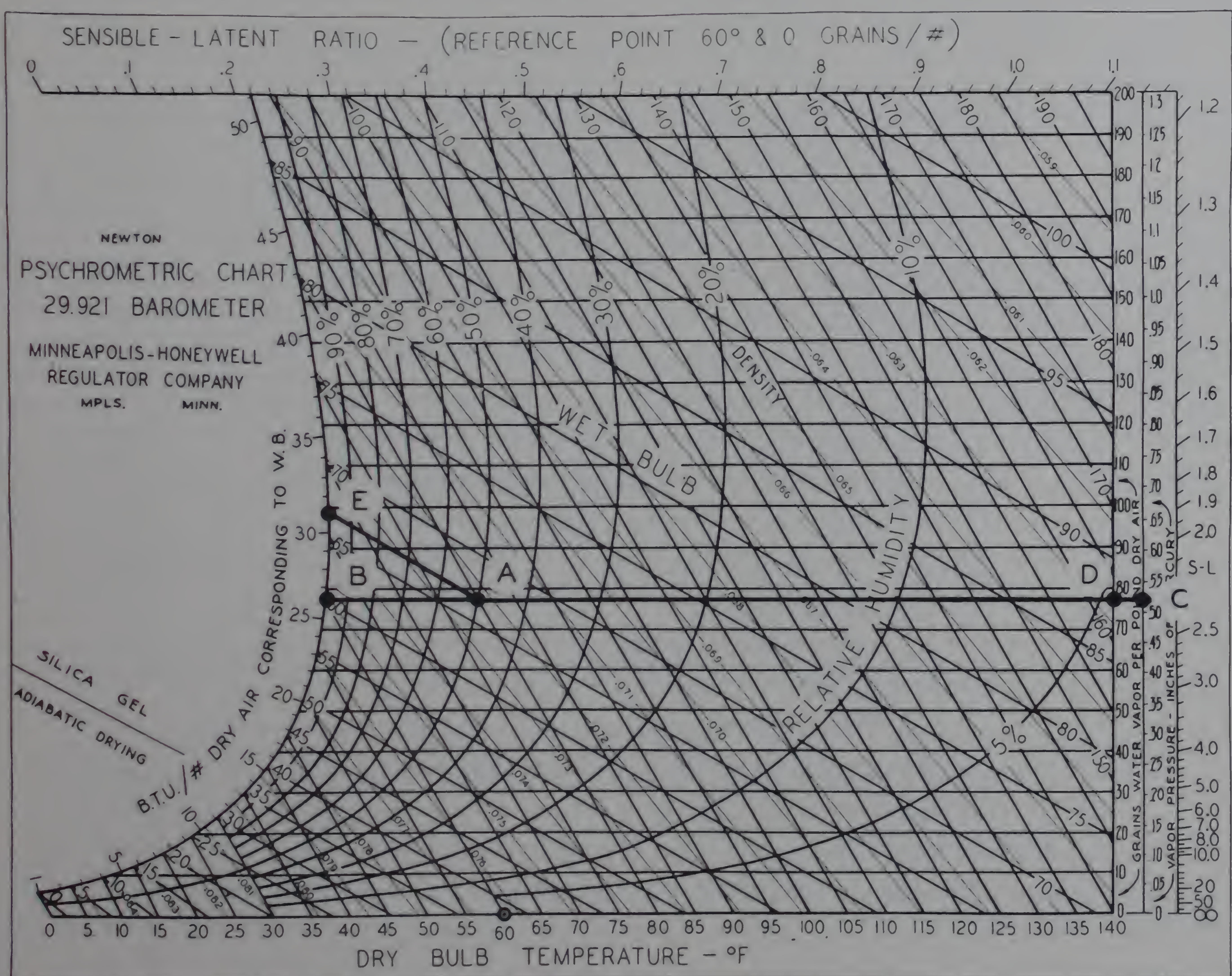


Figure 2

THEORY OF AIR CONDITIONING

II. Changes in the Properties of Air with Changes in Conditions

In Air-Conditioning there are five changes of conditions which are of primary interest. They take place when the following functions are performed:

1. Heating Air.
2. Cooling Air below its dew point.
3. Adiabatic Saturation.
4. Mixing Air at two different conditions.
5. Silica-gel adiabatic drying.

Heating Air

Referring to Fig. 3, "A" represents the condition of a quantity of air at 75° dry bulb and 62.5° wet bulb.

To show the change in conditions in heating the air to 100° dry bulb project a straight horizontal line to the right until it intersects the 100° dry bulb line at "B". This line is horizontal due to the fact that moisture is neither added nor removed from the air during the process. All conditions of this heated air may be read from the chart from the location of point "B".

Cooling Air Below Its Dew Point

If a horizontal line is projected to the right from point "A" Fig. 3, it will interesect the "Grains of Water Vapor per pound of dry Air" scale at 65, represented by point "C".

If the Air at "A" is cooled to the saturation point by a heat transfer surface not colder than its dew point the change in its properties may be represented by a horizontal line to the left intersecting the Saturation Curve at "D". It should be noted that "D" lies at the intersection between the 65 Grains of Water Vapor line, and the 55° dry bulb temperature line. Therefore this process has been carried on without changing the moisture content.

If, however, the air at condition "A" is cooled by a 40° F. spray, the process is represented by a straight line from "A" to the point where it intersects the 40° dry bulb line on the saturation curve. This point is shown at "E".

If a horizontal line is now projected to the right from "E" it will intersect the "Grains of Water Vapor" curve at "F", which shows that the air at this new condition has only 37 Grains per pound. From this it is shown that:

1. Air may be cooled to its dew point without a loss in moisture.
2. When air is cooled below its dew point its moisture content is reduced.
3. When air is cooled by contact with a surface the temperature of which is below the dew point of the air, its moisture content is reduced.

Adiabatic Saturation

Adiabatic saturation is defined as the process of saturating air with water vapor without adding or subtracting heat, in other words, at a constant wet bulb temperature.

To illustrate this process refer to point "A" Fig. 3. It will be noted that "A" lies on the 62.5 wet bulb line. If the air at "A" is saturated adiabatically, as it may be in passing through an air washer, the changes in its properties may be represented by projecting a line from "A" along the 62.5 wet bulb line until it intersects the saturation curve at "G". During this process:

1. The dry bulb temperature has dropped from 75° to the wet bulb of 62.5.
2. The wet bulb has remained constant at 62.5. Since the total heat value has not changed, it is obvious that part of the sensible heat has been changed to latent heat.
3. The grains of water vapor per pound have increased from 65 to 85.

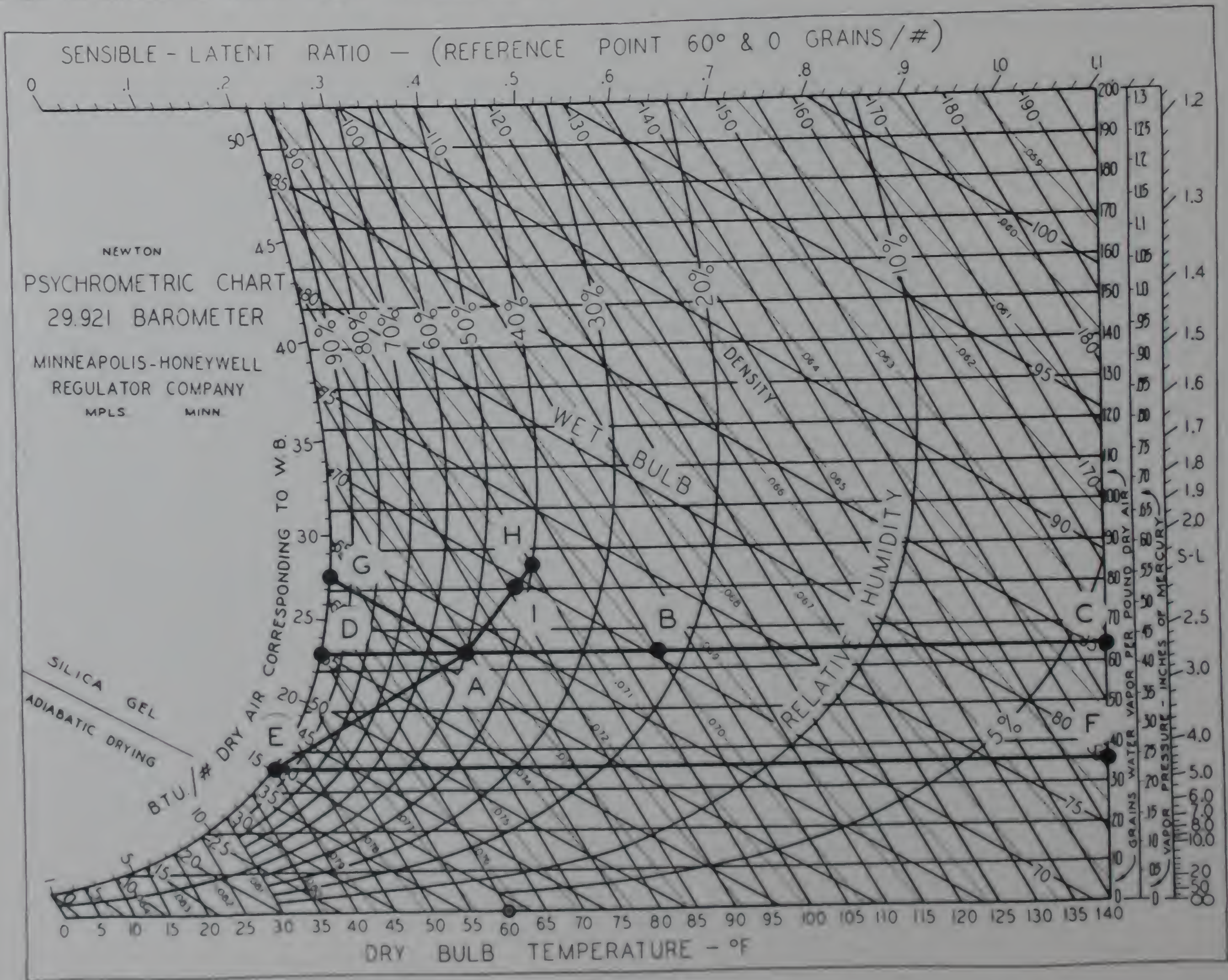


Figure 3

THEORY OF AIR CONDITIONING

Mixing Air at Different Conditions

It is desired to mix 10 pounds of air at condition "A", Fig. 3, with 30 pounds of air at condition "H", and to determine the condition of the mixture.

Condition "H" represents a dry bulb of 91° F., a wet bulb of 72° F. and 89 Grains of water vapor per pound.

It has been previously determined that point "A" represents a dry bulb temperature of 75°, a wet bulb temperature of 62.5° and 65 grains of water vapor per pound.

The condition of the mixture may be determined by arithmetic average as follows:

(a) Dry Bulb (sensible heat):

$$\frac{3\ (90)}{4} + \frac{1\ (75)}{4} = 86.3°$$

(b) Grains of Water Vapor (latent heat):

$$\frac{3\ (87)}{4} + \frac{1\ (65)}{4} = 81.3 \text{ grains}$$

Point I, Fig. 3, falls at the only point on the chart which will satisfy all of these values. Point I is also ¾ of the length of "A H" from A, and ¼ of the length of "A H" from H.

From this fact it is determined that mixing of air in any proportions can be represented by straight lines joining the points involved. When unequal quantities of air are mixed, the mixed air condition is inversely distant from the ends of the line in proportion to the per cent of the total air represented by each of the two ends.

Silica-gel Adiabatic Drying

Air enters a silica-gel unit at 80 degrees dry bulb and 67 degrees wet bulb and is de-humidified until 20 grains per lb. are left in it. What will be the temperature of the air leaving the silica-gel dryer under equilibrium conditions? From the 80 degree dry bulb and 67 degree wet bulb points draw to the right, parallel to the imaginary line from the silica-gel adiabatic drying line to the reference point at 60 degree dry bulb and zero grains per lb., to intersect the 20 grains per lb. line and read the dry bulb temperature as 124 degrees Fahrenheit leaving air temperature.

The fundamentals illustrated in the foregoing examples will be utilized in analyzing actual air-conditioning systems.

In the following sections an analysis of the basic operating characteristics of typical systems is made in order that definite conclusions regarding the limitations of control equipment may be drawn.

THE HEATING CYCLE

In winter air-conditioning systems separate equipment is usually employed to provide the functions of heating and humidifying.

When a thermostat calls for heat, the equipment is called into action to produce heat only. It produces no change in the moisture content of the conditioned spaces. As has been previously shown with reference to the chart, this simple heating process is represented by a horizontal line between the two temperatures involved. Thus, if air enters a heating coil at a temperature of 65° F. and leaves at a temperature of 110° F., its path on the chart is represented by a horizontal line between a point on the 65° dry bulb line and the 110° dry bulb line. The height of this line on the chart will be determined by the moisture condition of the air as it enters the coil. Without exception, the heating cycles with which we are concerned in the application of air-conditioning may be represented by horizontal lines of this type.

Humidification is accomplished by the vaporization of water, which process always requires heat from some source. This heat may be added to the water prior to the time vaporization occurs, or it may be obtained by transforming a portion of the sensible heat of the air being humidified to latent heat as the vapor is added to the air. In accomplishing this function the air may be brought into intimate contact with the water by:

1. **Breaking the water into a fine mist by means of sprays.**
2. **Passing the air over surfaces continually wetted by water.**
3. **Combining sprays and wetted surfaces.**
4. **Heating water in open pan.**
5. **Steam jet.**

Spray type humidifiers may be arranged to:

1. **Use recirculated spray water without preheating the air.**
2. **Use recirculated spray water and preheat the entering air.**
3. **Use heated spray water.**
4. **Use unheated spray water, not recirculated.**

When recirculated spray water is used and the air is not preheated, the heat required for the process of humidification must be obtained by converting a portion of the sensible heat of air into latent heat. Theoretically, the air leaving the washer and the spray water should be in exact balance at the wet bulb temperature of the entering air.

Since the wet bulb conditions of the entering air may not be constant, it is possible for the moisture content of the air and, of course, its final relative humiidty to fluctuate.

To prevent this fluctuation it is desirable to preheat the air to a temperature which has been computed as satisfactory. When this method is used, there is better assurance of the actual moisture content of the air leaving the humidifier.

In some cases the spray water itself is heated to the desired wet bulb temperature of the leaving air. In this type of installation, the heat transfer is from the water to the air being humidified and if the system is 100% efficient, the air will leave the humidifying chamber saturated at the temperature of the spray water.

The systems discussed above have been based on the use of recirculated water or water heated to a fixed temperature for spray purposes. They have also been considered as 100% efficient. The degree of efficiency of the washer type system will depend upon the arrangement of spray nozzles, the velocity of air through the chamber, and other physical characteristics which must be considered on each specific installation.

Many air-conditioning systems utilize a spray type humidifier which will consist of a single bank of spray heads using no recirculated water. These spray humidifiers do not saturate the air as completely as the washer type and the results obtainable from them cannot be as constant. If the water used is allowed to fluctuate in temperature, it is impossible to accurately determine the final leaving wet bulb temperature of the air.

In all of the humidifying systems discussed above it is usually necessary to provide some means of reheat to bring the final discharge air conditions to the proper level.

Fig. 4 represents a graphic interpretation of the changes in the physical properties of air as it passes through a winter conditioning system arranged to provide:

1. **Mixture of outdoor and return air in fixed proportions in a plenum chamber.**
2. **Preheating of the mixture.**
3. **Humidification with a washer type humidifier.**
4. **Reheat with steam heating coils.**

THEORY OF AIR CONDITIONING

It is required that room conditions be maintained at 72° F. and 40% relative humidity when the outside dry bulb temperature is 32° and the wet bulb is 27°. Because of an extreme problem of ventilation, it is specified that 2/3 outdoor air and 1/3 return air be used.

Point "A" represents the desired room condition and point "B" that of the outdoor air. Point "C", one-third of the way from "B" on the line "A B", represents the condition of the mixture.

Since this mixture is at a low temperature, it is necessary to raise its temperature in the preheater to such a point that proper humidification will be insured. The change in the properties of the mixture as it passes through the preheater may be represented by a horizontal line to the right from "C".

It is determined that a dew point of 50° is sufficient to provide for the moisture losses from the room, and since humidification in the spray type washer takes place at a constant wet bulb temperature, it is necessary to preheat the air to a 50° wet bulb.

The limit of the change which must take place in the preheater can, therefore, be represented by the intersection of the preheat line with the 50° wet bulb slope at "D".

As the air leaves the preheater it enters the humidifier and is saturated, if the washer is 100% efficient, without change in wet bulb temperature. The change in its properties may be plotted by following the 50° wet bulb line from "D" to the point where it intersects the saturation curve at "E". It should be noted that the dry bulb temperature has been reduced because of the evaporative cooling effect in the washer.

The final step in the conditioning process involves the function of reheat which takes place at a constant moisture content and is represented by the line "E F". Point "F" must be varied as the sensible heat loss from the conditioned space fluctuates. Thus the point "F" will be further to the right under extreme load conditions and further to the left as the weather becomes mild.

Conclusions:

1. The capacity of the heating and humidifying equipment must be sufficient to reach the limits as illustrated by points "D", "E", and "F".
2. Controls must be provided to maintain these limits if the specified room conditions at "A" are to be held constant under all loads.

Methods for effecting such control sequences are discussed in detail under the chapter on "Central Fan Heating Systems," page 18.

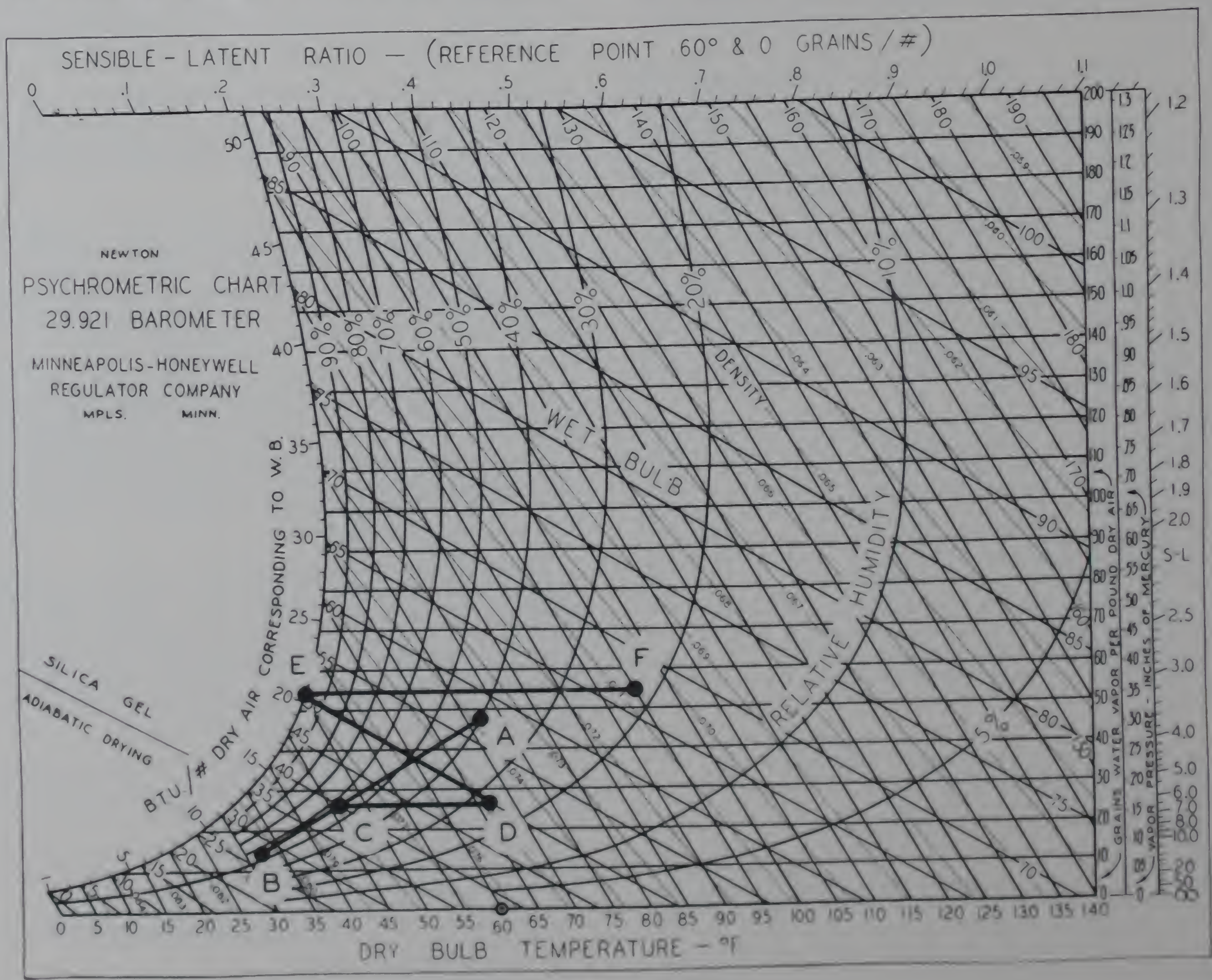


Figure 4

THEORY OF AIR CONDITIONING

THE COOLING CYCLE

In cooling cycle air conditioning installations the regulation of temperature and moisture content of the air is commonly accomplished simultaneously by the same piece of equipment.

Conditioning units which utilize a chilled water spray or cooled finned surfaces seldom provide any marked degree of cooling without at the same time dehumidifying the air. Likewise, it is impossible to do any considerable degree of dehumidification with this type of equipment without at the same time materially cooling the air. The reasons for these facts will be brought out in the psychrometric analysis of cooling cycle equipment.

In applying controls to summer conditioning systems it should be remembered that an instrument such as a thermostat which reacts only to changes in temperature causes the air conditioner to produce changes in humidity as well as changes in temperature. Frequently the fluctuations of the uncontrolled factor may be of far greater importance than any fluctuations likely to occur in the controlled factor. The actual amount of cooling and dehumidifying which must be accomplished will naturally vary from job to job. Likewise, the amounts of each relative to one another will vary in accordance with the type and location of the installation.

In order that the factors of dry bulb temperature and moisture content of the air be maintained within reasonable limits, it is necessary to determine for each installation the relation between the amounts of dry bulb cooling and dehumidifying which must be provided. A convenient index of the balance between these two cooling requirements has been established and is referred to as the S/L ratio.

The S/L ratio may be mathematically computed by dividing the sensible heat to be extracted in BTU's by the latent heat to be extracted in BTU's.

This ratio is frequently interpreted to represent some balance between the sensible and latent heat removed by the cooling surface in the conditioner, but in this discussion it shall refer to the ratio of heat removal required in the room. Actually the heat transfer takes place when the air discharged from the conditioner unit mixes with the air within the conditioned space.

The temperature and moisture content of the air discharged from the conditioner unit is usually below that of the air within the space. The discharge air is therefore capable of soaking up both sensible heat and moisture as it mixes with the room air. The relative amounts of sensible heat and moisture which will be transferred during this mixing process will determine the final dry bulb temperature and relative humidity which will be maintained.

The ratio of the BTU values corresponding to changes in dry bulb temperature and to changes in grains of moisture are utilized to establish the S/L scale. A line from a point on this scale to the reference point at the 60° mark on the bottom of the chart gives the slope of the corresponding S/L line on the chart. Any other parallel line on the chart represents changes at this S/L ratio.

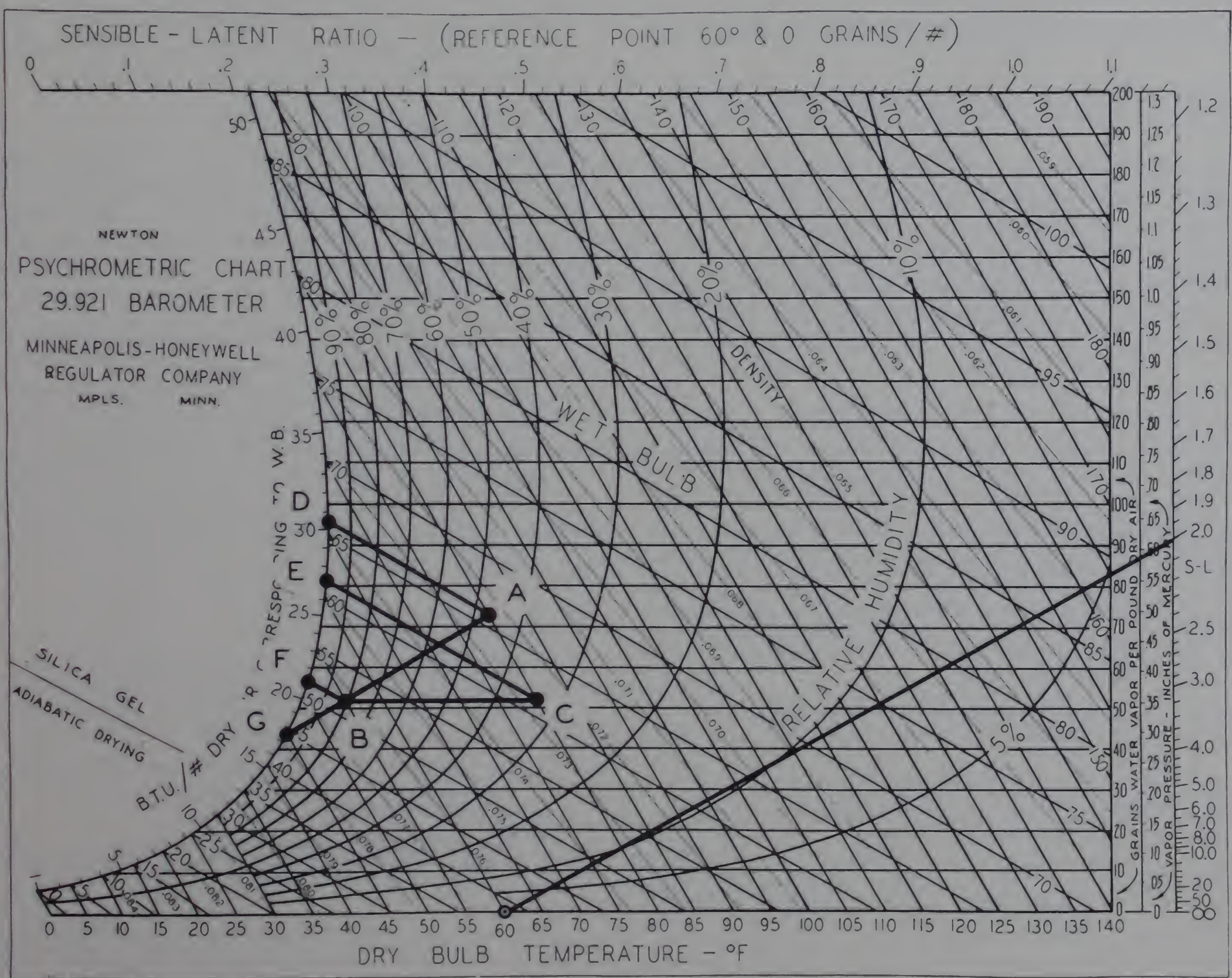


Figure 5

THEORY OF AIR CONDITIONING

Figure 5 illustrates the changes which take place in an air conditioning system of the recirculating type wherein it is desired to maintain room conditions at 80° dry bulb and 66° wet bulb temperature.

The sensible load has been computed at 300,000 BTU's per hour. The latent load is equivalent to 150,000 BTU's per hour. The S/L ratio or the relation between sensible and latent heat to be removed is therefore 2.0. Each lb. of air that is discharged by the conditioning system must therefore be able to absorb twice as much sensible as latent heat as it mixes with the room air.

Point "A" represents the desired room conditions and a line drawn thru "A" parallel to the 2.0 S/L slope will indicate the S/L relationship for the conditions under consideration. It is determined that the cooling equipment is of sufficient capacity to insure the delivery of air at 55° dry bulb and 52° wet bulb as represented by point "B" on Figure 5.

It should be noted that point "B" falls on the S/L slope drawn thru "A".

For purposes of analysis it may be assumed that as the air discharged from the cooling equipment at condition "B" mixes with the room air as represented by point "A", cooling may be considered in two steps:

1. Sensible cooling performed by the discharge air wherein its dry bulb temperature is raised without changing its moisture content
2. Latent cooling performed by the discharge air wherein its moisture content is raised with no change in its dry bulb temperature.

The line "BC" represents the first step in cooling the room wherein the dry bulb temperature of the discharge air is increased without changing its moisture content. Lines "BF" and "CE" represent the total heat in BTU per lb. of dry air at the two respective conditions. It is noted that in removing sensible heat from the room the BTU per lb. of discharge air has been increased from 21.5 to 27.5.

Step No. 2 is represented on the chart by the line "CA" which shows the moisture content of the air as it increases from 54 grains of water vapor per lb. to 73 grains of water vapor per lb. thus absorbing moisture from the room. Since both "A" and "C" fall on the 80° dry bulb line, no change in dry bulb temperature has been effected. Lines "AD" and "CE" represent the total heat at the two respective conditions and it is noted that in removing the moisture from the room, the BTU per lb. of discharge air has been increased from 27.5 to 30.5.

Therefore the ratio between heat removed in sensible cooling to the heat removed in latent cooling is 6/3=2.0.

Since the load has been computed to represent a 2.0 S/L ratio, it is obvious that sensible and latent heat are being removed in the proper proportions.

Any other point along the line "A-G" may be shown to provide the same ratio of heat removal. In other words, the air discharged from the conditioner must fall on this straight line in order to remove the proper proportions of sensible and latent heat.

The actual amount of air to be delivered from the conditioner is determined by the dry bulb temperature of the discharge. For example, the amount of air discharged may be determined by applying the formula:

$$\frac{\text{B. T. U.}}{\text{(Specific Heat) x (Temp. Diff.)}} = \text{Lbs. air per hour}$$

Substituting the values given in the example, the formula becomes:

$$\frac{300{,}000}{0.24 \times (80-55)} = 50{,}000 \text{ lbs. air per hour}$$

Converting lbs. of air per hour to CFM:

$$\frac{50{,}000}{.075 \times 60} = 11{,}100 \text{ C.F.M.}$$

Since it has already been demonstrated that sensible and latent heat will be removed in the correct proportions, it is then evident that 11,100 C.F.M. delivered by the conditioner at a dry bulb temperature of 55° F. and a wet bulb temperature of 52° F. will maintain the desired room conditions so long as the sensible load remains equivalent to 300,000 BTU's per hour and the latent load 150,000 BTU's per hour.

The same conditions could be maintained if air were delivered at any other point along the line "A-G" provided that the total quantity of air handled is changed sufficiently to provide the required amount of cooling .

Coil Temperatures

Referring again to Figure 5 it will be noted that if the S/L ratio line is extended, it will intersect the saturation curve at point "G" representing 45°. This point approximately represents the average surface temperature of a fin coil which will be required to provide a discharge temperature which will fall on the S/L slope drawn thru "A".

The characteristics of a fin type coil indicate that only a portion of the air is brought into intimate contact with the finned surfaces, the balance passing between these surfaces without being appreciably cooled. The discharge temperature from a finned coil would therefore represent a mixture of cooled air at 45° and recirculated air at condition 'A". The point on the line "A-G" corresponding to this mixture will be determined entirely by the efficiency of the coil.

Conclusions:

1. *To maintain both temperature and relative humidity at specified values, air must be delivered at a condition represented by some point falling on the straight line on the psychometric chart drawn thru the room condition at the required S/L slope*
2. *The termination of this line at the saturation curve represents the approximate average fin temperature required to give the desired S/L ratio.*
3. *The total CFM required is determined by the position of the point on this line representing the condition of the air leaving the coil.*

The use of these theoretical determinations will be illustrated in the following analysis of typical summer air conditioning systems.

THEORY OF AIR CONDITIONING

AIR WASHERS

Fig. 6 provides a graphic illustration of the changes in a quantity of air passing through a washer type cooling unit.

The equipment under consideration is arranged with a circulating fan, duct system, and a spray type washer around which a return air bypass is constructed. For purposes of this illustration consideration of outdoor air mixtures is omitted.

The system under discussion is required to maintain room conditions at 80° and 50%. The sensible load is computed at 240,000 BTU's sensible and 160,000 BTU's latent.

Analysis:

The S/L ratio is found by the equation

$$\frac{240,000}{160,000} = S/L = 1.5$$

The slope of this ratio is shown on Fig. 6. Point "A" represents the desired room conditions of 80° and 50%. Since 1½ times as much sensible heat as latent heat must be absorbed from the conditioned space if the desired conditions are to be maintained at "A", it is obvious that the temperature of the delivered air must be somewhere on a line from "A" parallel to the S/L slope.

Since air may be considered as leaving a washer in a saturated condition, the point of intersection between a line through "A" parallel to the S/L slope and the saturation curve will indicate the water temperature necessary to meet the specified load condition. This point at "B" indicating that the required washer temperature is 40°.

The line "A-B" indicates the change in condition of the air after it leaves the washer and absorbs heat from the conditioned space until it comes into perfect balance with the conditioned space at the desired room conditions.

Since a portion of the return air is being by-passed around the washer, the temperature of the air leaving the conditioner will be determined by the standard "Mixed Air" procedure and will fall at some point "D" on the line "A-B". The location of "D" relative to "A" and "B" will depend upon the relative proportions of air passed through and around the washer, as previously described.

It should be noted that the air at "D" is considerably below the saturation point and one value of the by-pass in this type of system is that it prevents saturated air from being discharged into the room.

When the variations in sensible and latent load which will be encountered are unknown on an installation where this type of equipment is to be used, it is impossible to guarantee both temperature and humidity conditions.

It would be quite possible to expect a constant temperature or a constant humidity even with simple air washer equipment without reheat, but maintenance of constant humidity might often result in uncomfortably low temperatures.

Where it is possible to use re-heat, the air may be cooled to a point which would normally fall away from the computed S/L slope. When this occurs, the addition of heat through re-heater coils will in effect raise the sensible load to such a point that a new S/L ratio may be established which will allow the design conditions to be met.

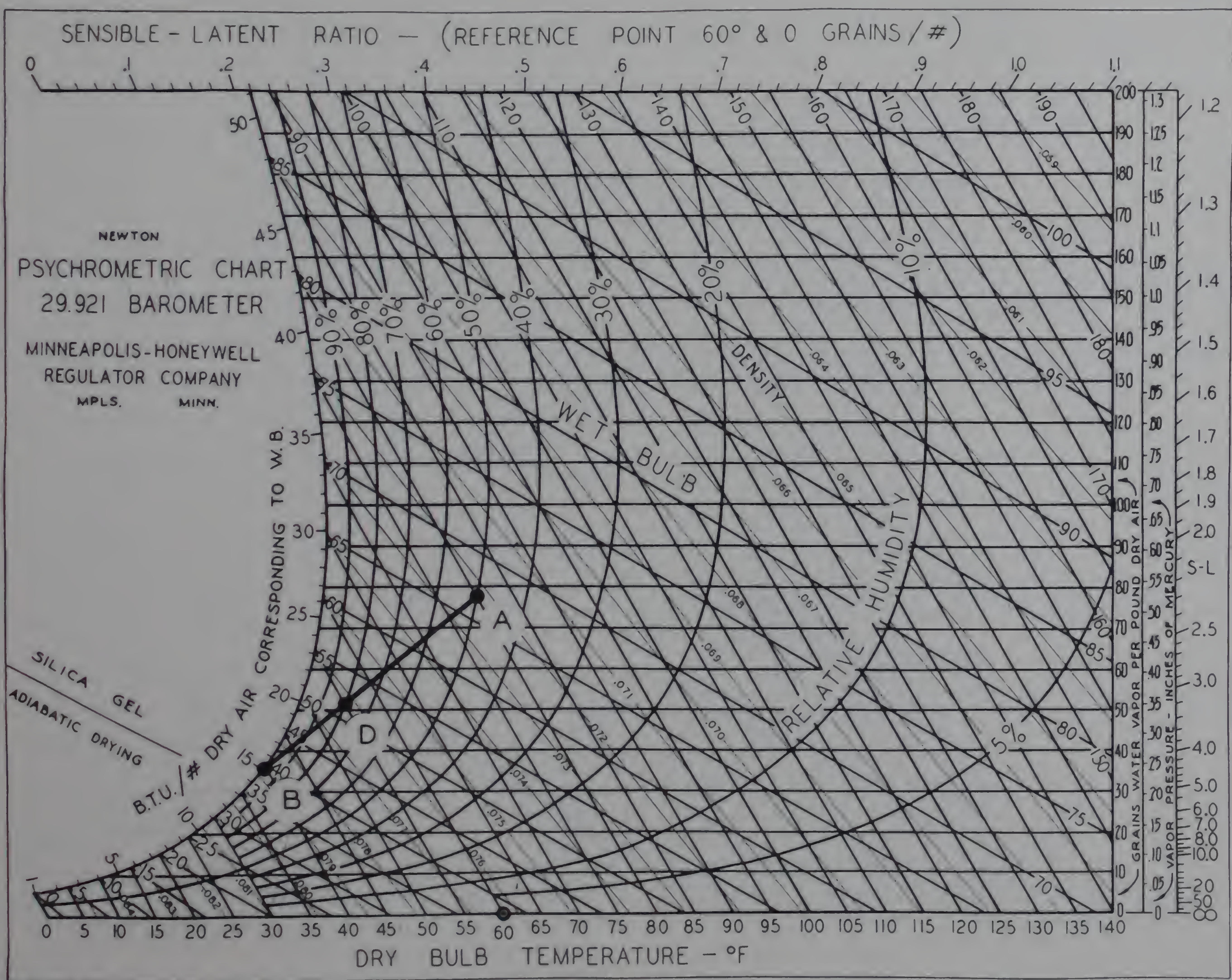


Figure 6

THEORY OF AIR CONDITIONING

FINNED COIL AIR CONDITIONING EQUIPMENT

In addition to the air washer type summer air conditioning equipment discussed above, many systems utilize finned coils to provide the functions of cooling and dehumidification.

Some form of refrigerant is circulated through these coils, thus reducing the surface temperature sufficiently to provide cooling and dehumidification of air passed over them.

In making a psychrometric analysis of systems using finned coils, the average fin surface temperature replaces the average water temperature as described in the air washer example above.

Obviously the average water temperature is easily measured while the average temperature of a finned surface is difficult to determine. This average surface temperature is affected by the temperature of the refrigerant in the tubes of the coil and also by the cooling load on the fins. Under conditions of high heat transfer through the fins, the temperature rise from the refrigerant to the tube surface will be higher than under light load conditions. Likewise, the temperature rise along the fins away from the tubes will be greater under the heavy load condition.

The discussion of the finned type coil air conditioners must be considered under two separate classifications:

1. Those units in which refrigerant is supplied at a substantially constant temperature regardless of load conditions.

2. Those units in which the refrigerant temperature is affected by the total load on the system, or is varied by mechanical control means.

UNITS USING WATER OR BRINE COILS

Fig. 7 illustrates the changes in a quantity of Air passing through a unit Air-Conditioning system employing chilled water coils as the heat exchange medium. Water is delivered to the coils from a cooler tank in which the water is maintained at a constant temperature by controls acting directly upon the mechanical refrigeration equipment. Air is circulated over the coils at a fixed velocity. The load within the conditioned space is computed at 250,000 B.T.U.'s sensible and 100,000 B.T.U.'s latent. The specifications require that room conditions be maintained at 80° dry bulb and 50% relative humidity.

Analysis

Point "A" on Fig. 7 represents the desired room conditions of 80° and 50%. The S/L ratio is computed as follows:

$$\frac{250{,}000}{100{,}000} = S/L = 2.5$$

Therefore the slope of the S/L ratio may be graphically represented by drawing a line from the reference point on the dry bulb temperature scale to the 2.5 mark on the S/L scale.

A line drawn through point "A" parallel to the S/L slope will intersect the saturation curve at a point which will represent the average fin temperature which will maintain the specified room conditions under the computed load balance. From the chart this temperature is found to be 53°.

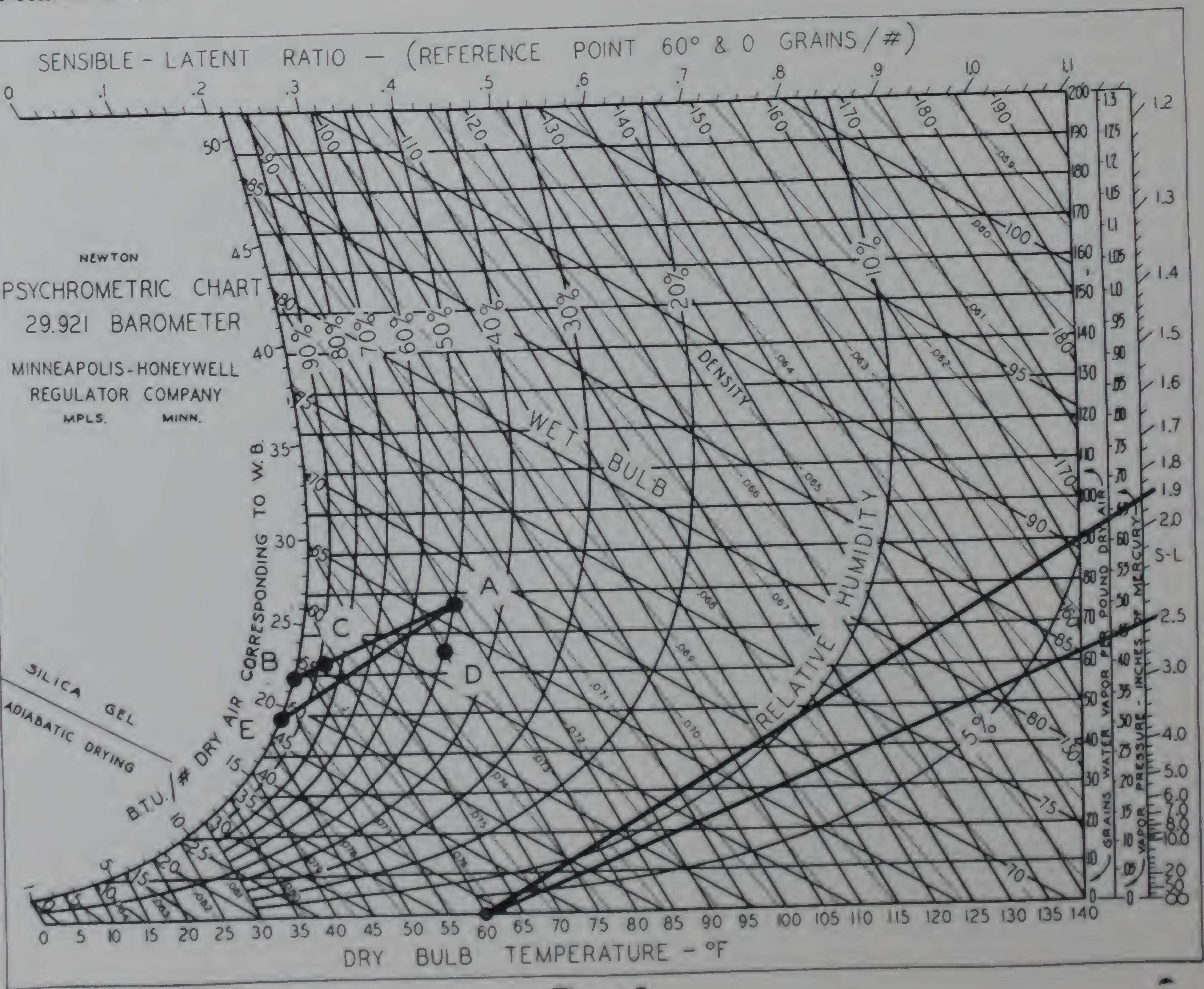


Figure 7

THEORY OF AIR CONDITIONING

It should be noted that as long as the ratio between sensible and latent load remains 2.5 no other average fin temperature will maintain the exact room conditions, since it is not possible to draw a line between "A" and any other point on the saturation curve which will at the same time be parallel to the S/L slope 2.5.

When a coil of the finned type is used the discharge temperature from the coil is always higher than the average coil surface temperature. This may be explained by assuming that only a portion of the air is in intimate contact with the fin surface, and the remainder passes through the openings between fins without being appreciably effected. The discharge temperature would then result from a mixture of return air and conditioned air, and the temperature of this mixture might be determined by the standard air mixture procedure. On Fig. 7 this value is represented by point "C".

As the total air-conditioning load decreases the S/L ratio usually decreases. When this occurs it is necessary to change the coil temperature of the unit correspondingly if the room conditions are to be maintained. If the refrigerant temperature is constant one way to slightly effect this change is through varying the velocity of the air passing over the coil. This will result in a reduction of the load on the coil and a consequent decrease in average fin temperature to some point "E", shown on the chart as 48°. With this lowered coil temperature it is possible to maintain room conditions when the S/L ratio has decreased to 1.9. This is determined by drawing a line parallel to "AE" through the reference point and noting its point of intersection with the S/L scale. Varying the air velocity has a much more decided effect in systems using direct expansion coils.

Frequently an operating sequence is specified wherein dry bulb temperatures are to be reduced during mild weather conditions, but relative humidity maintained at the same level. Point D represents a specified condition of 75° and 50% relative humidity.

It should be noted that an S/L slope drawn parallel to either "BD" or "ED" would result in an S/L ratio higher than 2.5. This means that to provide the conditions at "D" the latent heat load would necessarily have to be reduced with respect to the sensible load. This, however, is contrary to actual conditions, since in mild weather the need for dehumidification tends to increase with reference to the requirement for cooling.

Conclusions

1. A control system should not be specified to maintain both lowered temperature and humidity during mild weather unless reheat is provided. One of the two factors may be controlled at a reduced level, but the second will fluctuate within the limits of the conditioning equipment.

2. Adequate control equipment should be provided to maintain water temperatures constant and also to vary the velocity of air over the coil with respect to temperature changes. These systems are discussed in detail under Central Fan Cooling System, page 32.

UNITS USING VARIABLE TEMPERATURE — REFRIGERANTS —

In addition to the units discussed above, many systems are so arranged that the refrigerant temperature is varied under the control of the desired room conditions or else is automatically varied as the load changes due to the natural reactions of the various portions of the system. Chief among these systems are the direct expansion refrigeration systems. The majority of direct expansion systems utilize a constant speed compressor to maintain a low temperature in the cooling coils. It is a characteristic of such systems that the greater the load on the cooling coils, the higher will be the temperature of the refrigerant in the coils and the greater will be the capacity of the compression equipment. This fact works out to our advantage in air conditioning work.

The changes in refrigerant temperature that take place on a mechanical refrigeration system as the result of variation in machine capacity, air volume, coil area, or refrigerant flow can be made use of to very good advantage to provide desirable conditions through the entire range of cooling requirements. Directing these characteristics in the proper channel is a function of the control applied to the installation. Following are some examples of the effects of various methods of capacity reduction on a refrigeration system.

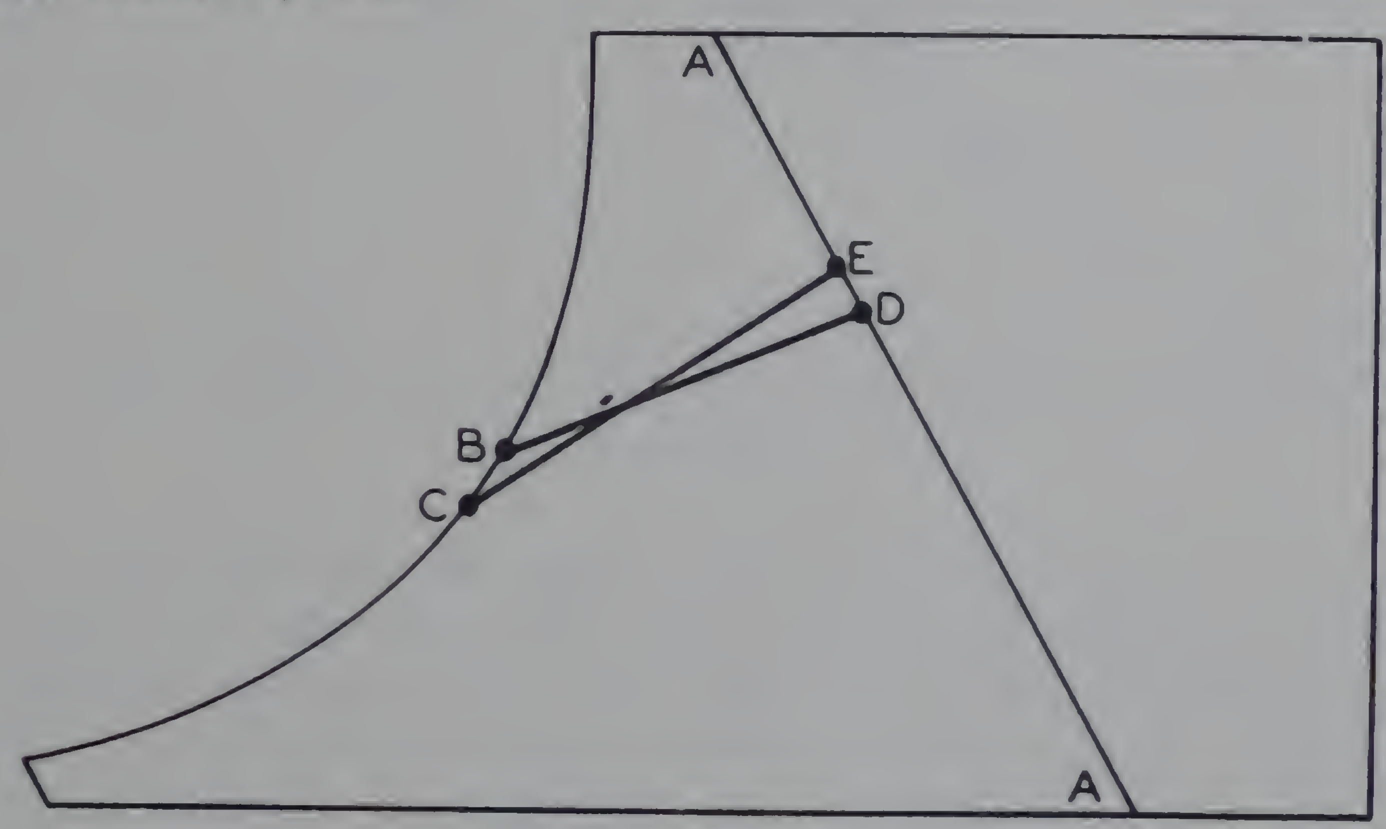


Figure 8

1. Single Coil Installation—"On-Off" Control

Fig. 8 illustrates the condition resulting from this type of control. Assuming that the installation under consideration has an S/L ratio of 2.5 under the most severe load conditions, it will usually be found that under mild load conditions the S/L ratio is much more severe, i.e. usually more latent cooling is required in proportion to sensible cooling at light loads.

We can assume therefore that under a mild weather condition the extreme S/L ratio will be 1.75. With an "On-Off" control system, point "B" will represent the coil temperature under maximum load condition. Under mild weather conditions there will be a slight drop in coil temperature due to the decrease in the entering wet bulb temperature. This would be represented at point "C." Assuming that we wish to maintain the temperature constant along line "A-A," then under maximum load conditions the room conditions maintained will be represented by point "D" (projecting the line on an S/L ratio of 2.5 from point "B").

THEORY OF AIR CONDITIONING

Then under mild weather conditions our room conditions would be as represented by point "E" (projecting a line from point "C" along a ratio line of 1.75). It is obvious therefore that under mild weather conditions with a more severe S/L ratio, that in maintaining the room temperature at the same level an increase in relative humidity conditions will result.

2. Variation of Air Volume

Another very common method of reducing the capacity of the coil and the rate of cooling is accomplished by reducing the amount of air passing over the coil. This is accomplished by means of dampers located in front of or adjacent to the coil which are controlled in a modulating manner from room temperature or humidity. Under the extreme load conditions the coil temperature would be as represented by point "B" (figure 9) and therefore with an S/L ratio of 2.5, the room conditions maintained would be as represented by point "D" since the temperature is being maintained constant along line "A-A".

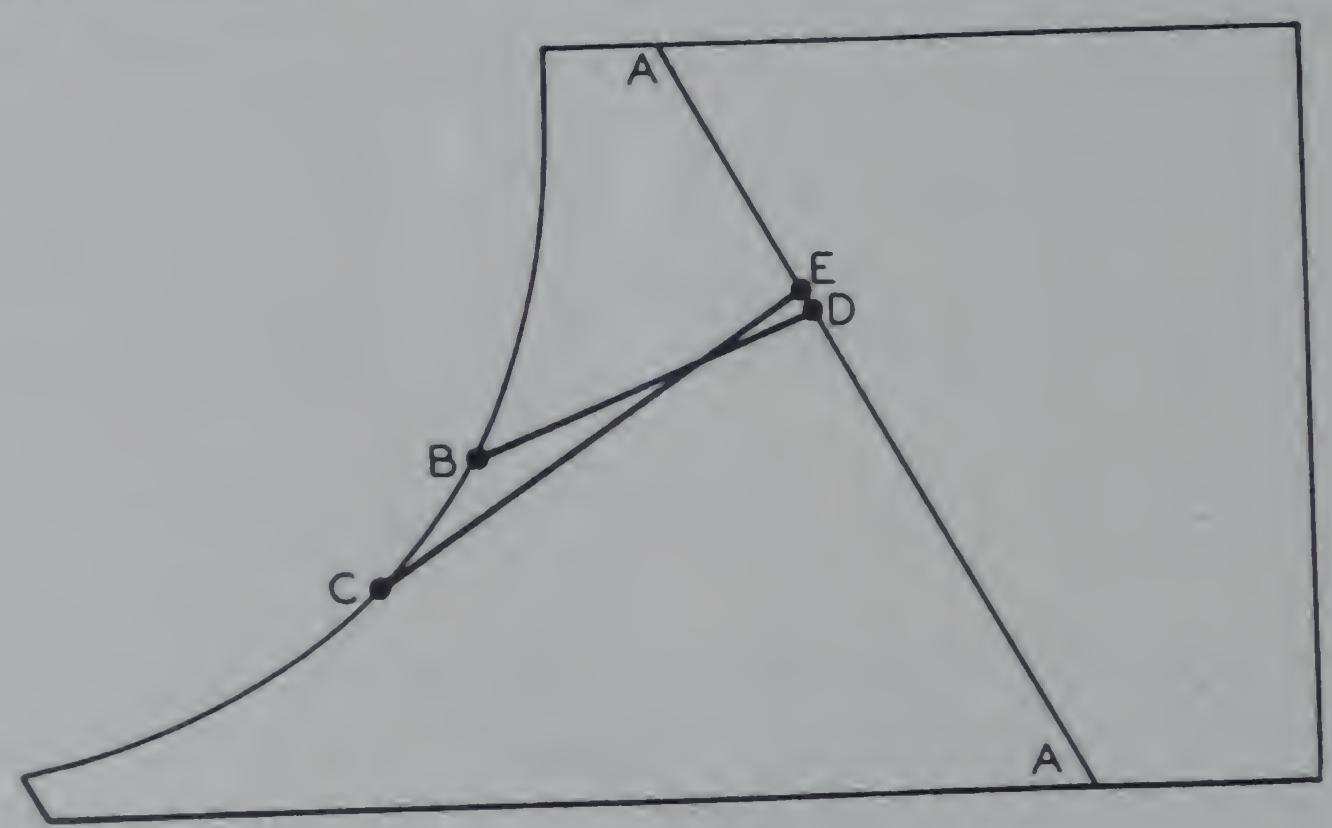


Figure 9

As the load drops off, the dampers will throttle to a position restricting the air flow over the coil. As this is accomplished, the load on the coil will be correspondingly reduced. A reduction in coil temperature will result. The extent to which the coil temperature can drop is limited by the refrigerant temperature at which frost will accumulate on the coils. Therefore at a definite suction pressure representing this limiting condition it is usual practice to cut off the refrigerating machine in order to prevent this frost accumulation.

Under mild load conditions the coil temperature would be some point such as represented by "C". It should be noted here that the point "C" is not as low as the minimum coil temperature accomplished with the Modutron System. It is found possible to reach lower coil temperatures with the Modutron system in view of the fact that the rate of air flow over the coil is not reduced while in varying the air flow over the coil, the reduction in rate of air flow will cause frost to accumulate at a slightly higher coil temperature.

If the S/L ratio for mild weather conditions is again 1.75, we find that the room conditions maintained under this load will be as represented by point "E".

It should be noted that it is possible to obtain lower relative humidity conditions with the system that varies the air volume than is possible with the single coil system (Fig. 8).

3. Adjustment of Machine Capacity

The refrigerating effect can in many cases be controlled by reducing the capacity of the refrigerating machine. This reduction can be made through the control of variable speed motors, variable speed drive mechanisms or by the adjustment of throttle on gas driven engine drives. Two-step adjustment of machine capacity is very common and is accomplished by the use of two-speed motors, multiple condensing units, clearance pocket control or cylinder by-pass control. Frequently several machines will be installed and sometimes each machine will have further means for adjusting its capacity which will provide a number of steps of capacity reduction.

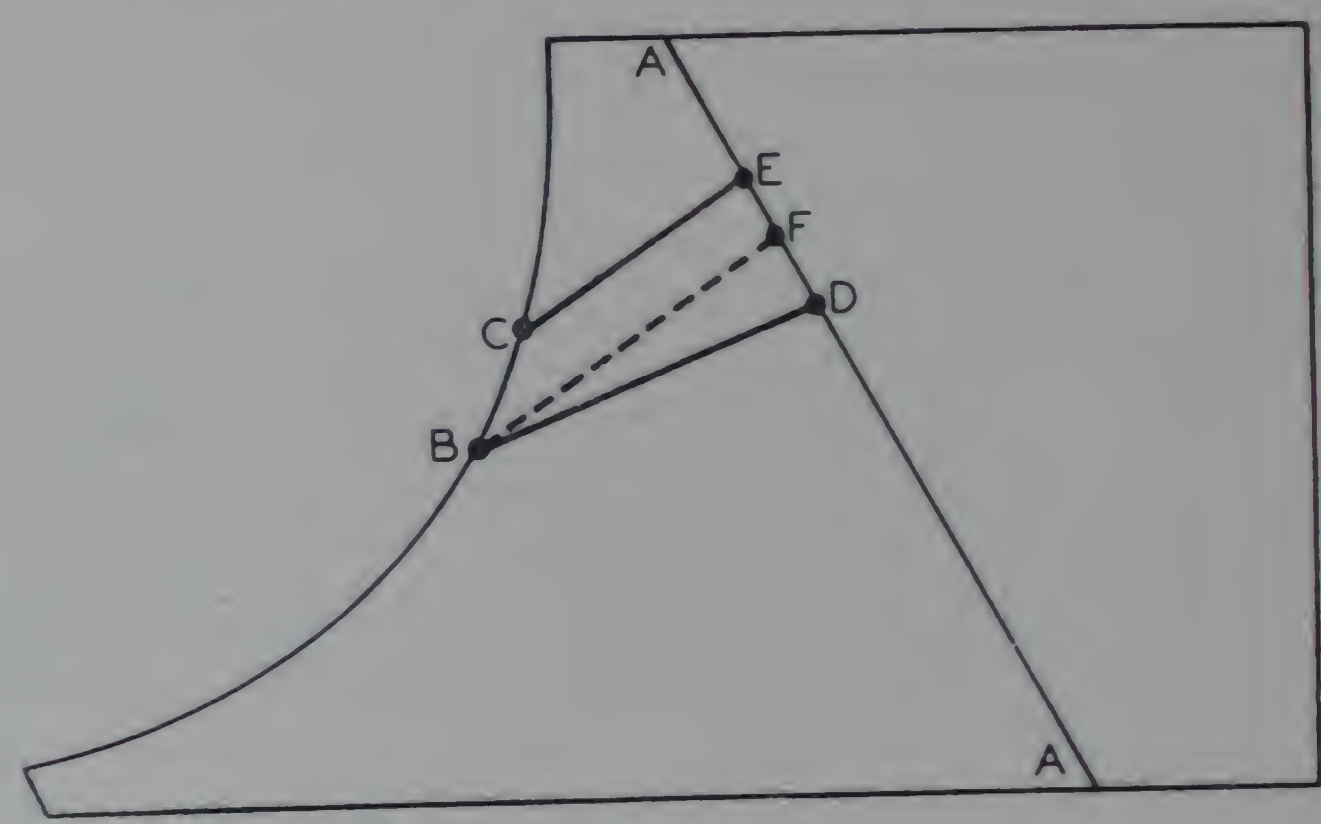


Figure 10

Fig. 10 illustrates the effect of the adjustment of machine capacity in the case of a two-step adjustment (such as two-speed motor control, clearance pocket or cylinder by-pass). Under maximum load conditions the coil temperature would again be some point such as represented by point "B" and with an S/L ratio of 2.5, we find that again the room conditions would be as represented by point "D" where we are maintaining the dry bulb temperature along line "A-A". If the machine capacity is dropped to a lower point, an increase of coil temperature will result. Therefore, under mild load conditions if this type of installation were controlled by temperature alone, the coil temperature would rise to some point such as represented by point "C". With an S/L ratio of 1.75 we can then determine that the room conditions maintained under mild load conditions would be a point such as represented by point "E". It is apparent therefore that in controlling a system of this type from a simple two-step thermostat that frequently the control will be improper by reason of the fact that the relative humidity maintained will suffer an increase during mild load conditions where the problem of keeping relative humidity within limits is usually most severe.

A system of this type should include a humidity controller which would have the power of determining the speed at which the motor operates or of determining the capacity level. In this case the use of such a humidity controller would cause the machine to be operated on maximum capacity under this particular load condition so that with the same S/L ratio of 1.75, we would find (extending a line from point "B" at a ratio of 1.75) that the room conditions would be at some point as represented by point "F".

THEORY OF AIR CONDITIONING

The use of such a control will also permit within the limits the maintenance of relative humidity at a desired point, as obviously if the desired relative humidity falls some place between point "E" and point "F", partial operation at first one point and then the other as determined by the relative humidity control would result in a net relative humidity some place between the two points as required.

In any of the examples cited above, it is obvious that if the dry bulb temperature is to be maintained at a desired point, then it is possible to control the relative humidity only down to the point which is determined by the S/L ratio which is effective for that particular load condition. The minimum coil temperature is limited by the design of the installation. Therefore, in order to maintain relative humidities at any lower point on the line "A-A" in any of the systems described above, it is clearly necessary to add reheat to the air passing through the coil in order to yield a relative humidity condition as desired. In order to provide this result the air must be artificially heated without affecting its dew point so that the condition of the leaving air will be moved horizontally to the right on the chart far enough to yield the proper relative humidity.

Control of Central Fan Heating Systems

Central fan systems for heating and air-conditioning consist of many separate pieces of apparatus designed to provide any or all of the following functions:

1. **Heating.**
2. **Humidification.**
3. **Ventilation.**
4. **Distribution.**
5. **Air cleaning.**
6. **Cooling by use of cool outdoor air whenever necessary.**

There are many variations in the physical arrangement of equipment used to accomplish the functions outlined above and the selection of a method which will prove most satisfactory for a specific installation will depend upon local practice, and local climatic and economic factors.

When more than one function is to be accomplished by a single system, particular care must be exercised in arranging and interlocking the equipment so as to provide a completely coordinated sequence of operation. The use of automatic temperature control provides a satisfactory and economical means of accomplishing this coordination.

In the following sections the factors affecting heating, humidification, ventilation, and atmospheric cooling will be discussed separately and the application of automatic controls to the equipment used for these purposes will be analyzed.

CONTROL OF HEAT SUPPLY

Winter conditioning systems may be divided into two general types.

1. **Tempering Systems for Ventilation Only**

In systems of this type the mixture of outdoor and return air is delivered at space temperature for ventilation only. The actual heat losses of the space are then provided for by means of direct radiation.

2. **Blast Systems for Heating and Ventilating**

In this type of system the heating surface in the fan system is made large enough to not only temper the mixture of outdoor and return air, but also provide for the heat losses from the conditioned space.

TEMPERING SYSTEMS WITH PULL-THROUGH FANS

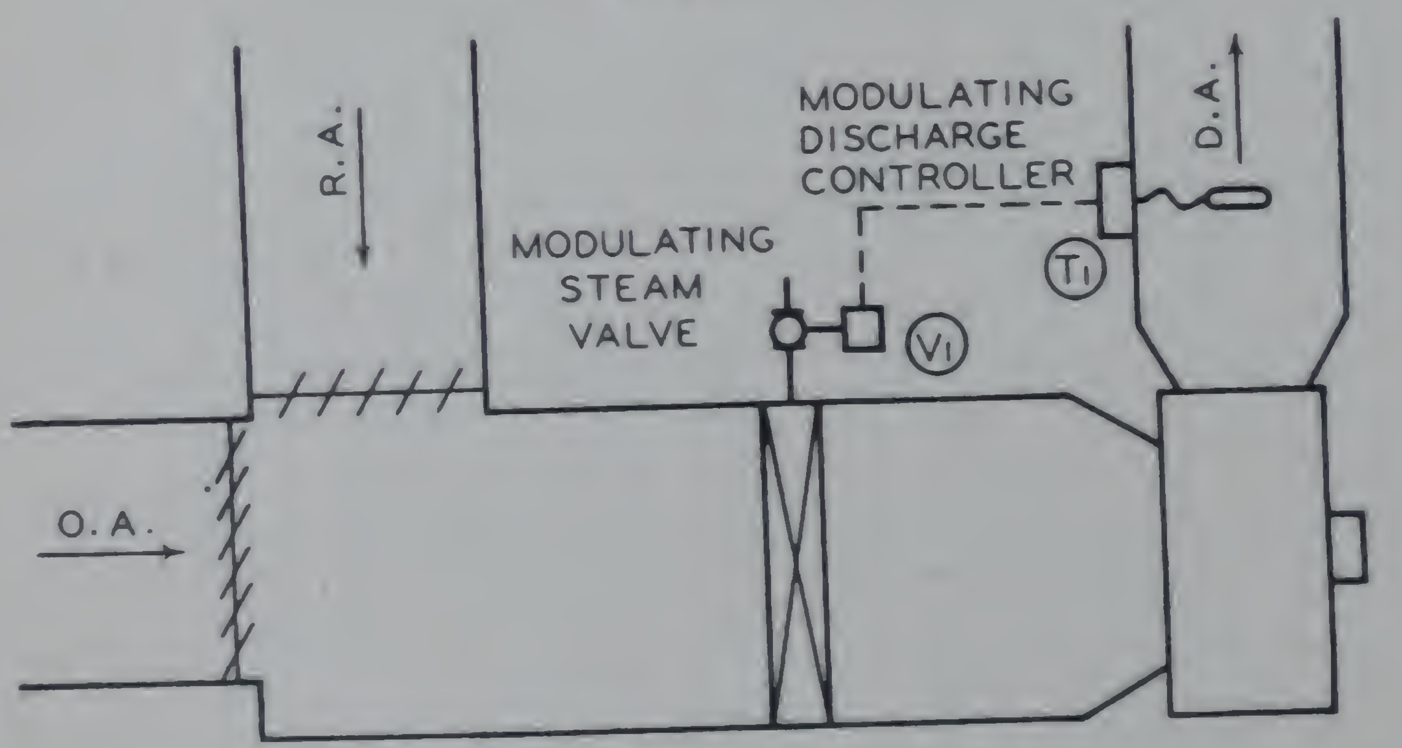


Figure 1

Fig. 1 illustrates a pull-through type fan system utilizing a mixture of outdoor and return air. The mixed air passes through the heating coil to the fan from which it is discharged to the ventilated space. Since this is a tempering system only, it is desirable to maintain a constant discharge temperature.

A modulating controller in the fan discharge operates a modulating steam valve on the heating coil to provide just sufficient steam to maintain the desired discharge conditions.

A two-position type of control should not be used since it would cause alternate high and low discharge temperatures as the valve opened and closed.

In choosing equipment for this application care should be taken to size the modulating valve correctly. Due to the rapidity of air movement through the heating coil, a discharge control system must be accurate if drastic conditions are to be avoided. If, for example, the valve used is twice as large as necessary, then the valve positions from one-half open to open would not change the temperature of the discharge air since by the time the valve is half open the heating coil will be completely filled with steam. Likewise if the maximum necessary pick-up through the heating coil is 30° and if the heating coil is large enough to heat the air to 60°, it is evident that when the coil itself is operating at more than 50% of capacity the air discharged will be at a temperature higher than that desired.

From these facts it is possible to draw the following conclusions:

1. **When a valve is sized larger than necessary, the controller loses effective positions.**
2. **When both valve and heating coil are larger than necessary, discharge temperatures will fluctuate widely.**

It is therefore of the greatest importance that the question of properly sized steam valves be considered carefully. The required capacity of the valve should not necessarily be based upon the actual capacity of the heating coil, but rather, upon the limiting conditions of air temperature entering the coil and the discharge temperature desired.

Valve Sizing

The following simple formula determines the maximum pounds of steam per hour that must pass through a valve for any given application.

$$Q = \frac{(\text{CFM}) \times 1.0 \times (T_b - T_m)}{1000}$$

Where: Q = lbs. of steam per hour, at 0 lbs. gauge.

T_b = Maximum discharge air temperature desired.

T_m = The minimum temperature of mixed outdoor and return air delivered to the coil.

Capacity tables in Section Eight give the steam capacity in lbs. per hour for different types of valves at various pressure drops. From these tables it is possible to select the valve which will pass the proper quantity of steam as determined by the above formula.

Usually the pressure drop through a valve cannot be absolutely determined without considerable calculation. However, for normal vacuum heating systems with an initial pressure of 2 lbs. gauge, a 1 lb. pressure drop may be normally assumed. For systems with a 5 lb. initial steam pressure, a 2 to 3 lb. drop may be assumed. These pressure drops will, of course, vary slightly due to piping layouts. However, for the average application they may be accepted as substantially correct.

Freeze-Up Protection

Due to space limitations in commercial air-conditioning it is sometimes difficult to place outdoor and return air duct work connections so as to provide a thorough mixture of air before delivery to the heating coil. If a condition of stratification exists to any considerable extent, it may be possible for outdoor air at a temperature below the freezing point to pass through portions of the heating coil. If a throttling type valve is used on the coil, special precaution must be taken to prevent freezing of the steam condensate by this cold air. Therefore, where throttling valves are used, care should be taken to assure the complete mixing of outdoor and return air by means of baffles or other methods.

There are types of heating coils available which have distributing tubes to supply steam equally to all parts of the coil even under conditions of throttled steam supply. This type of coil surface provides another possible method for freeze-up protection.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

BY-PASS SYSTEMS

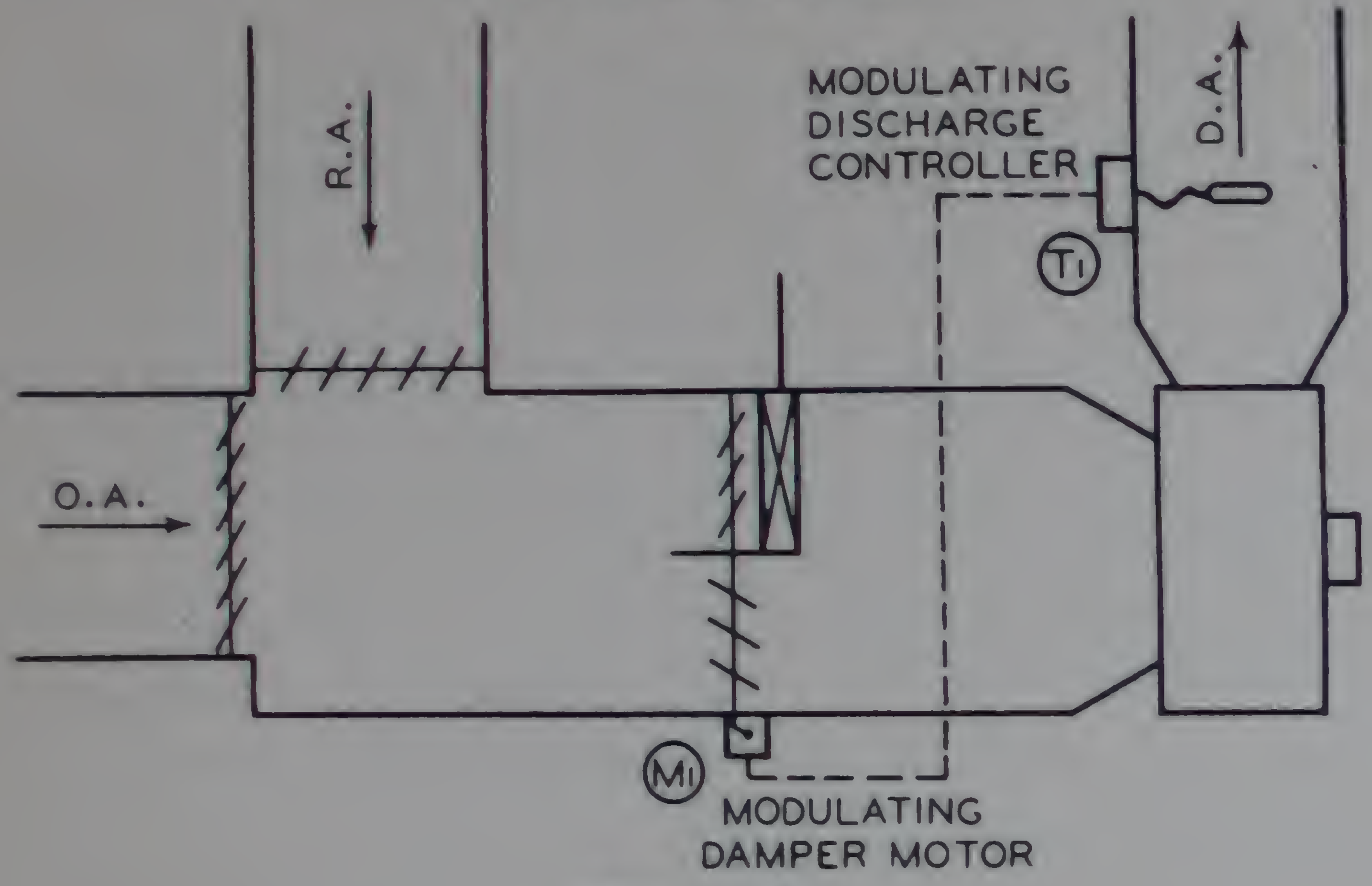


Figure 2

As shown in Fig. 2 installations are often made where the heating coil does not extend from the top to the bottom of the duct work. When this practice is followed, the air may pass either through or around the heating coil, provided that suitable dampers are installed to cause the proper deflection of air flow. The advantages of this particular arrangement are:

1. The modulating motorized face and by-pass dampers move in opposite directions at the command of a modulating discharge controller and thereby proportion the relative amounts of air passed through and around the heating coil so as to maintain a constant discharge temperature.
2. There is no danger of freezing the heating coils since it will be full of steam at all times.

It is difficult to obtain commercially manufactured dampers of the type illustrated in Fig. 2 which are 100% tight. Consequently, when the mixture of outdoor and return air is near the temperature desired for the discharge air, there is apt to be overheating due to the leakage of air through the dampers and due to eddy currents. In order to prevent this condition it is desirable to provide some means of final shutoff on the steam supply to the coil.

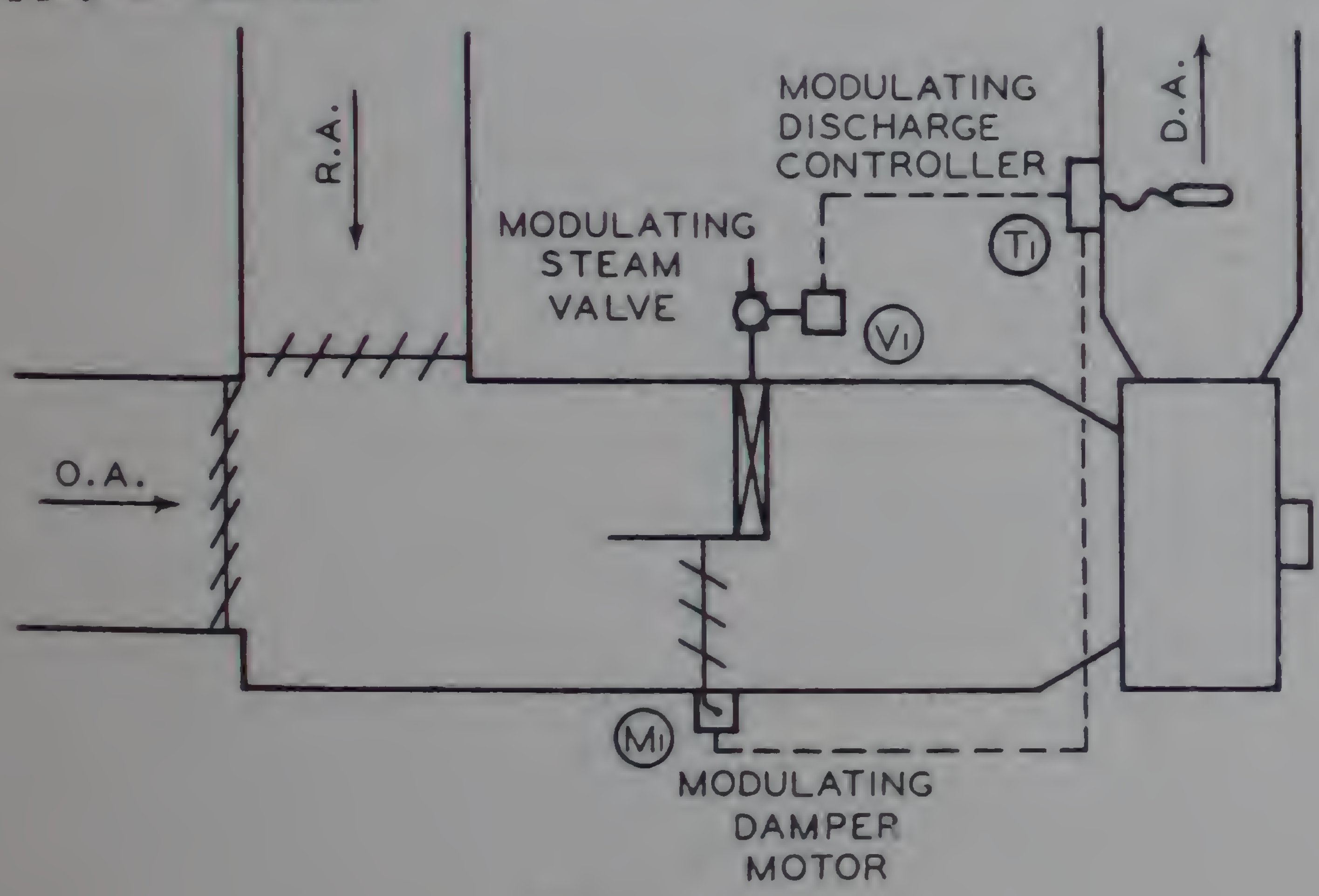


Figure 3

Fig. 3 illustrates a system similar to that in Fig. 2 with the addition of a valve on the steam supply line to the coil. No face damper is used. This system can be used where danger of coil freezing is not present. The advantages of this system are:

1. The steam valve and by-pass damper are modulated together at the command of a modulating discharge controller. As the steam valve throttles, the by-pass damper opens, thus reducing heat delivery.
2. There is no danger of overheating in mild weather due to the fact that the steam supply is completely shut off when the mixed outdoor and return air temperatures rises to the setting of the discharge controller.

This system is an improvement over that shown in Fig. 2 inasmuch as the possibilities of overheating are eliminated.

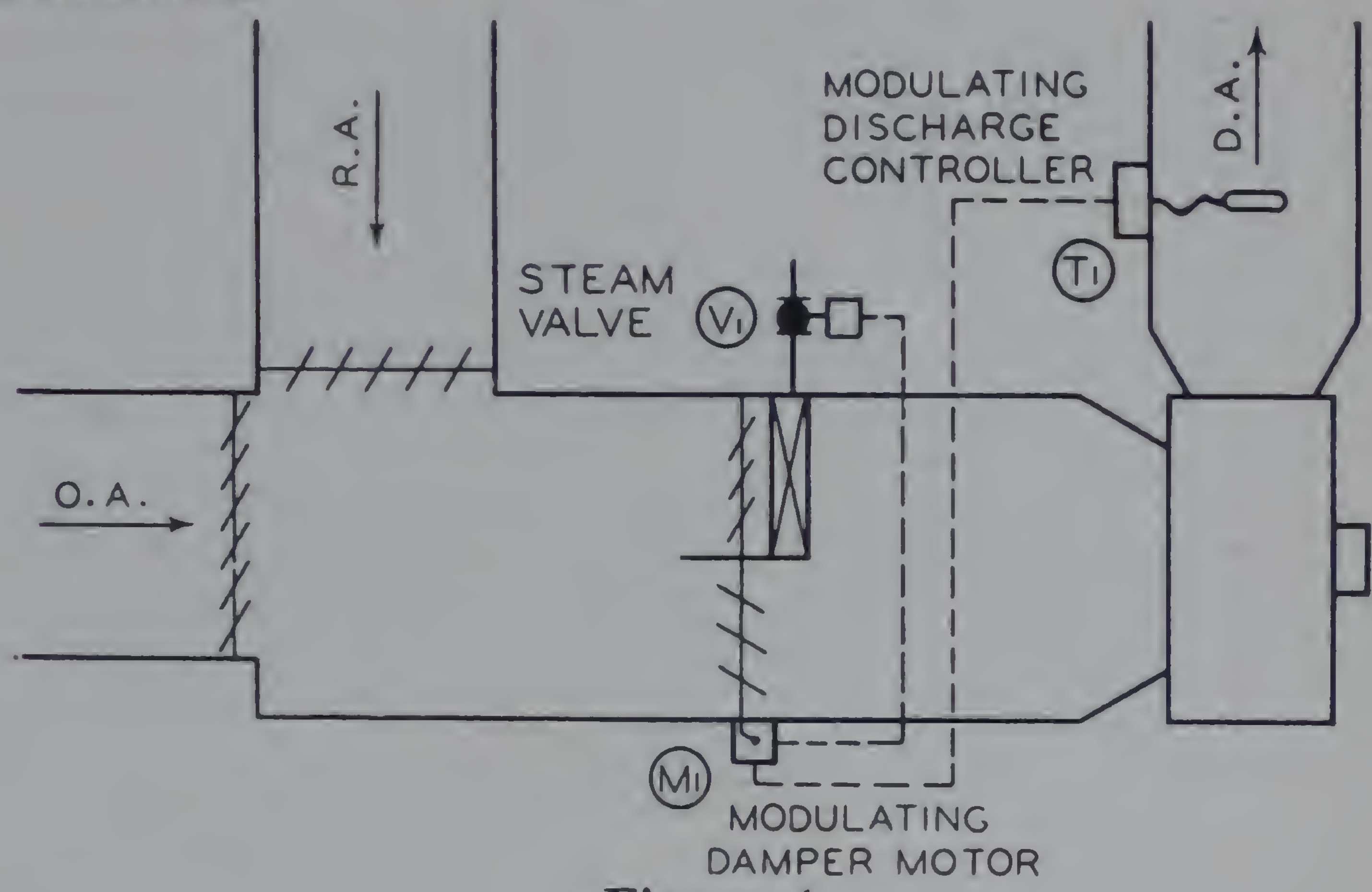


Figure 4

The system illustrated in Fig. 4 is used on applications where there is danger of admitting sub-freezing air across the face of the heating coil.

In this instance the modulating discharge controller positions the face and by-pass damper in order to maintain a constant discharge temperature.

The system is so arranged that the action of the face and by-pass damper motor will cause throttling of the steam valve as the face damper approaches the closed position. That is, at such time as the face damper is closed, the steam valve will also be closed and at such time as the face damper opens by a predetermined amount of its total travel, the steam valve will have modulated to the full open position.

It should be noted that two-position steam valves should not be used in applications of this type because of the fact that a certain amount of leakage may result even where a face damper is used. This may cause rapid cycling of the valve on and off under extremely light load conditions. If a face damper is not used such cycling will be very pronounced.

In the system shown in Fig. 4, the face damper is not always necessary when the by-pass damper is used, inasmuch as throttling action on the steam valve is obtained over the final portion of the control range.

Since the valve will be wide open at times when the by-pass damper around the coil is near the closed position indicating a severe load condition, the valve will be wide open when there is danger of sub-freezing air coming in contact with the coil.

NOTE: In all discharge control applications it is desirable to use motors on both valves and dampers which have relatively fast timings. Discharge controllers should include the adjustable differential feature to permit matching to the job.

TEMPERING SYSTEMS BLOW-THROUGH FAN

In the blow-through type fan system the heating coil is placed on the discharge side of the fan instead of on the suction side of the fan as in the previous examples.

This particular arrangement of equipment is usually found on those installations where both heating and ventilating is to be provided. When used to deliver constant temperature discharge air for purposes of ventilation only, considerable difficulty is encountered in the application of controls for this type of system.

As has been previously pointed out, where constant discharge temperatures are to be maintained, it is necessary to utilize a throttling type valve on the central fan

CONTROL OF CENTRAL FAN HEATING SYSTEMS

heating surface. When this type of valve is employed on a blow-through type fan system, it is possible for the air to leave the heating surface in a stratified condition due to the fact that the coil itself will not be completely full of steam whenever the valve is in a partially open position. The presence of this condition would have the following effect on the ventilating system:

1. The heat supplied to the ventilated area may be unevenly distributed with warm air at some outlets and cold air at others.
2. It is extremely difficult to find a satisfactory location for the temperature control bulb since the temperatures across the discharge ducts will vary materially with changes in valve position.

In order to overcome these effects special precaution should be taken to insure proper mixing of the air leaving the heating coil. This may be accomplished by baffles or by providing a sufficiently long run of duct work before any take-off is made.

There are also types of heating surface available which are arranged for even distribution of steam to the entire coil surface even under throttled control valve position. This type of surface will usually eliminate any difficulty due to stratification.

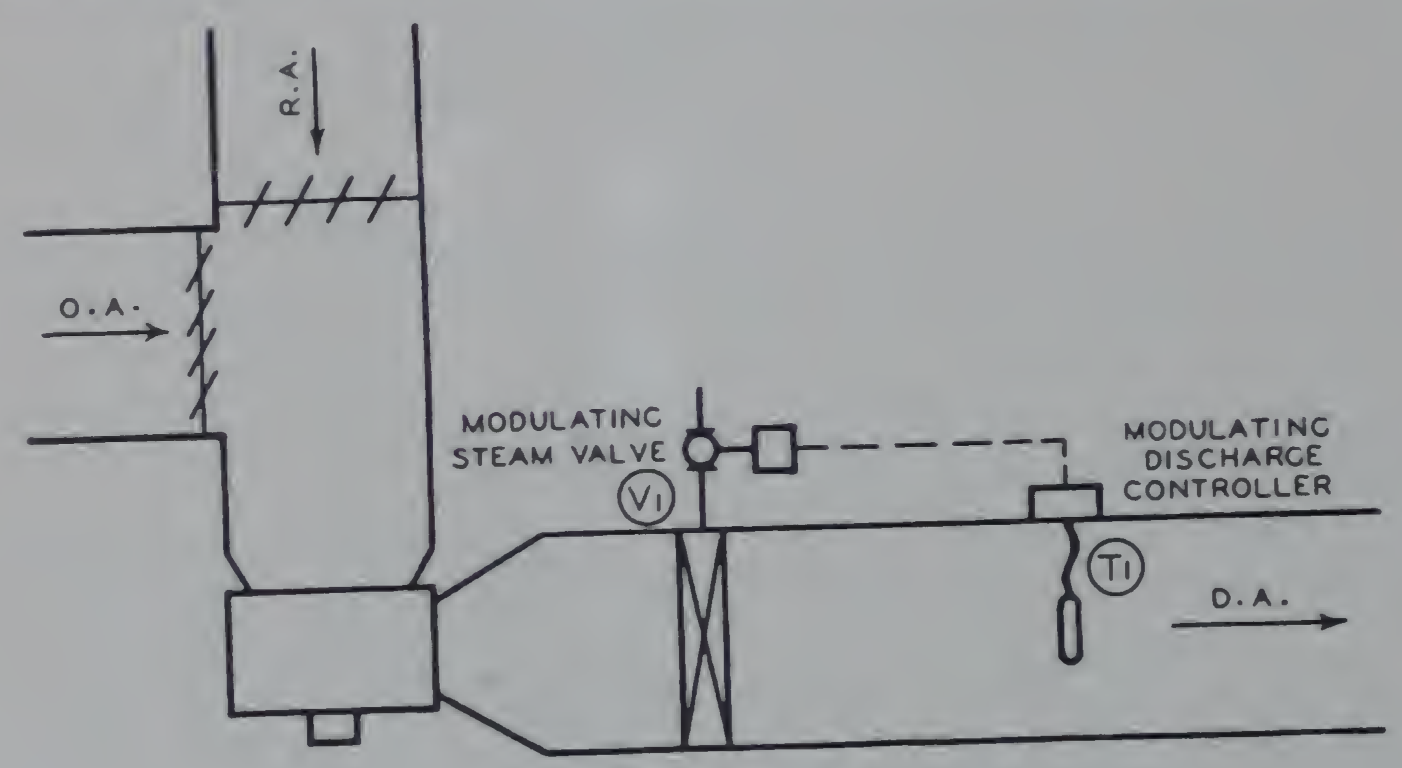


Figure 5

Figure 5 illustrates a simple blow-through tempering system. One of the outstanding advantages of the blow-through type system is found in the fact that the danger of coil freeze-up will be eliminated due to the fact that the outdoor and return air is thoroughly mixed in passing through the fan and unless the quantity of outdoor air taken in is sufficient to bring the whole mixture down below the freezing point, freezing air will rarely pass across any portion of the coil surface.

As in the case of pull-through fan systems, it is necessary to exercise extreme care in selecting a valve of proper size if the discharge temperatures are to be properly maintained.

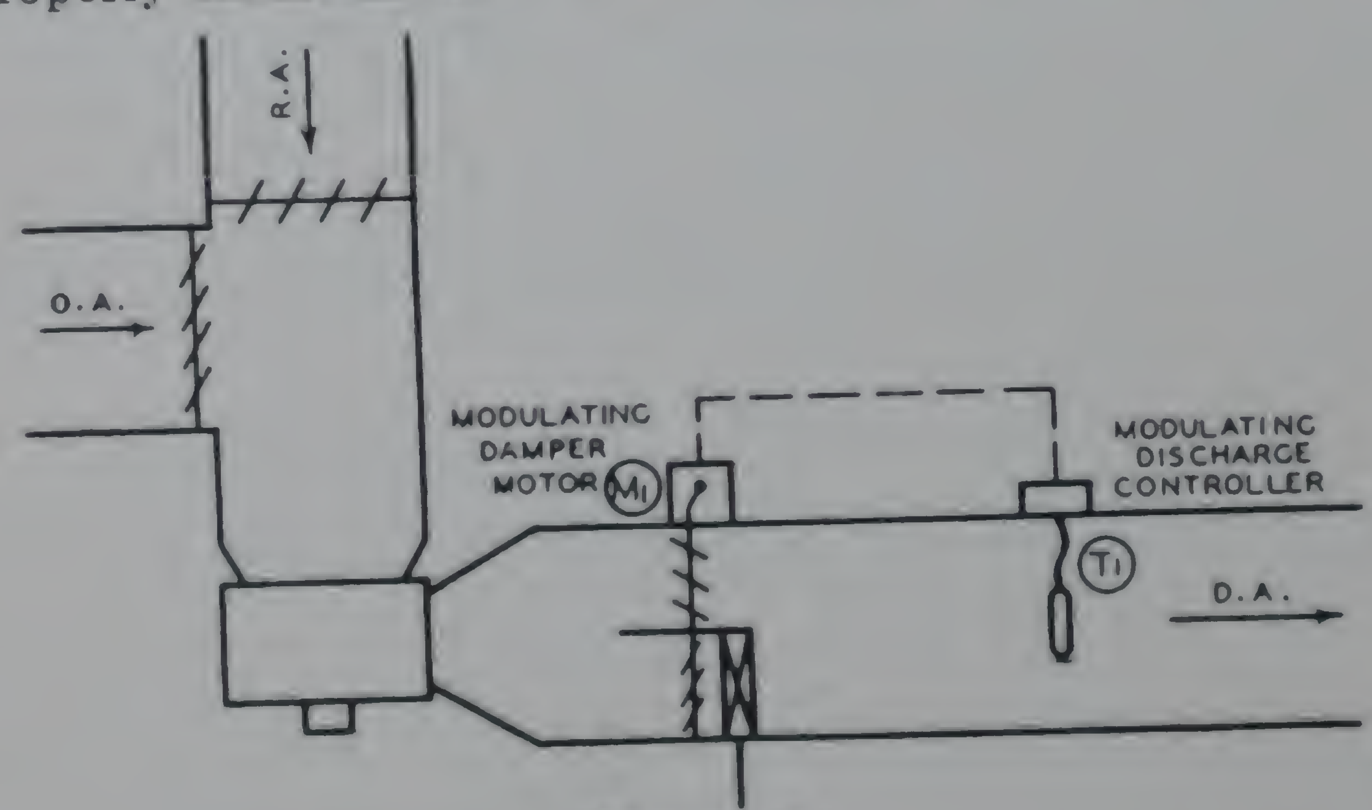


Figure 6

Fig. 6 illustrates a system of automatic control utilizing face and by-pass dampers in front of and around the heating coil. No valve is used on the coil and it is kept full of steam at all times. This system has the following advantages:

1. The relative amounts of air passed through and around the coil are varied at the command of the discharge temperature controller in order to maintain temperature at a fixed point. (As previously discussed, it is necessary to provide an adequate means for thoroughly mixing the air leaving the coil).
2. Positive protection against coil freeze-up is provided even under conditions where sufficient outdoor air is taken into the system to depress the temperature of the mixture to a point below freezing.

As has been previously pointed out, there is normally little danger of freeze-up in a blow-through type of system. There is, however, the possibility of overheating during mild weather unless some means is provided to completely shut off the supply of steam to the heating coil during mild weather.

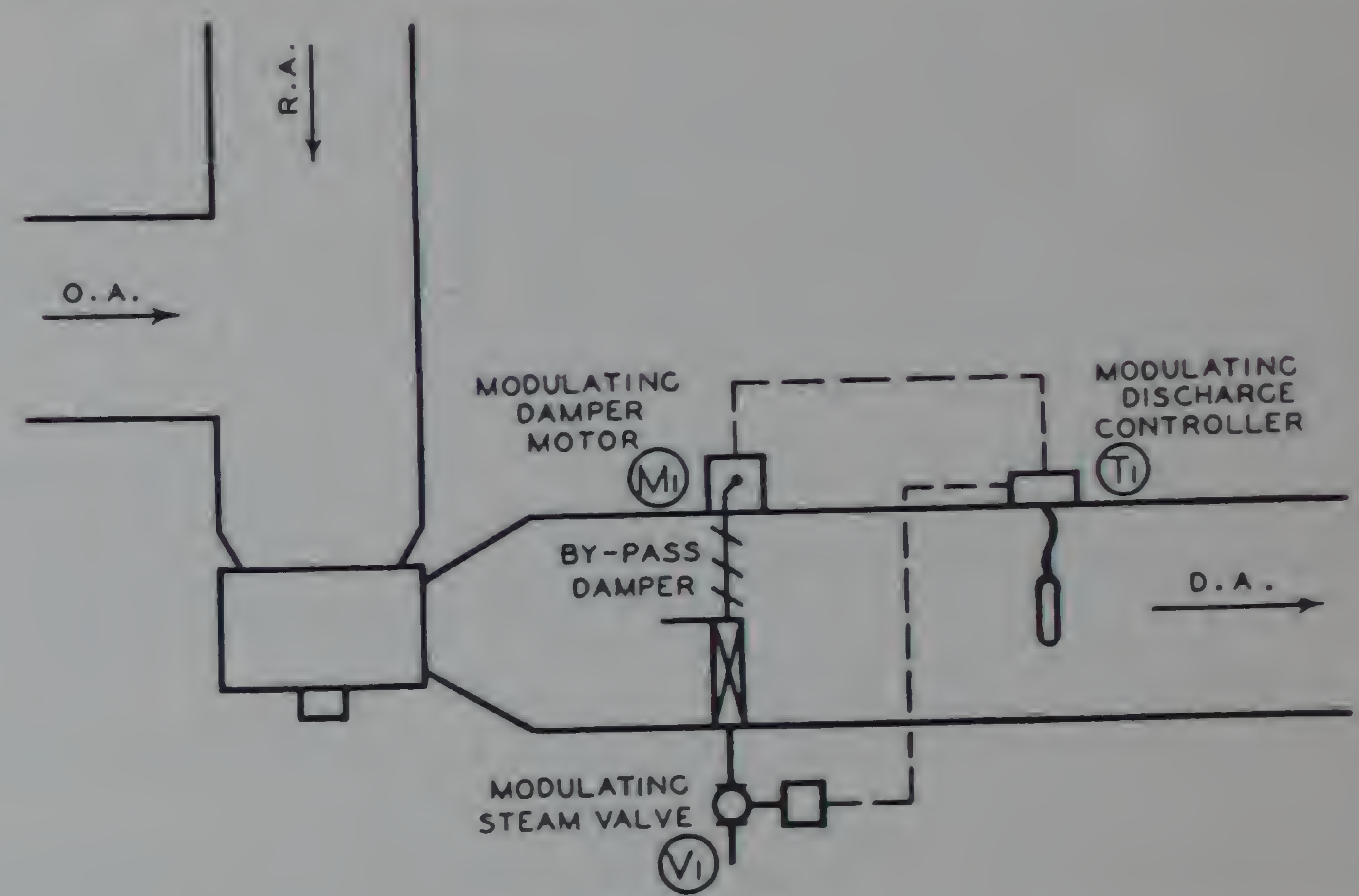


Figure 7

The control arrangement as illustrated in **Fig. 7 provides:**

1. Operation of the motorized steam valve at the command of a modulating discharge temperature controller to proportion the steam flow according to heating requirements.
2. Positive protection against overheating in mild weather is assured since the steam valve returns to a fully closed position as the mixture of outdoor and return air temperatures rises to the desired discharge control point.

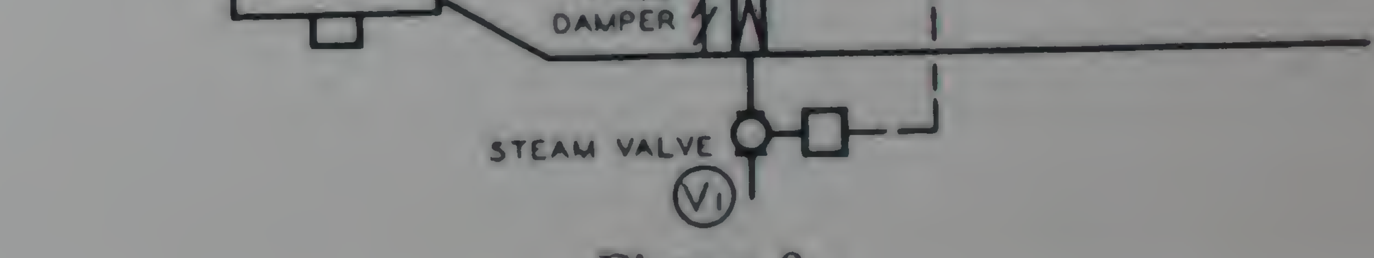


Figure 8

On those installations where it is necessary to provide protection against freeze-up as well as elimination of the possibility of overheating during mild weather, the equipment should be arranged as illustrated in **Fig. 8.**

CONTROL OF CENTRAL FAN HEATING SYSTEMS

The advantages of this type of control sequence are:

1. Motorized face and by-pass dampers and steam valve are operated at the command of a modulating discharge temperature controller to maintain distribution temperatures at the required level.
2. The danger of freezing the heating surface is elinminated since the steam valve will always be in a wide open position when the mixture of outdoor and recirculated air is near the freezing point.
3. Overheating during mild weather will be eliminated since the steam valve will go to a tight closed position when the mixture of outdoor and recirculated air approaches the desired discharge temperature.

BLAST HEATING SYSTEMS

The systems shown in Figs. 1 through 8 may be increased in capacity to the point where they will provide sufficient heat to offset external heat losses as well as for ventilation.

When a system is designed to provide this extra heating function, it is necessary to:

1. Select a heating coil of such size that the discharge temperature may be raised to a point which will allow actual heating within the conditioned space.
2. Use an additional temperature controller of the room or return air type as a pilot instrument.

In a typical blast heating system the automatic control sequence should provide the following functions:

1. Should the space temperature fall below the setting of the return air or room thermostat, the position of the steam valve and dampers should be changed to provide additional heat. As the space temperature rises toward the control setting, the room or return air instrument should gradually move the steam valve or face damper toward its closed position to reduce the amount of heat supplied.
2. Should the temperature of the space rise above the control setting, the return air or room-type instrument should close the steam valve completely or close the face damper and open the by-pass damper.
3. If the discharge air temperature should drop below a predetermined minimum, the discharge air controller should open the steam valve and face damper sufficiently to raise the discharge air to its minimum temperature level.
4. Protection against the possibility of freezing the heating surface should be provided.
5. Overheating during mild weather should be eliminated.

As described in the analysis of Figs. 1 through 8, care should be exercised to:

1. Select a steam valve sufficiently large but not oversized.
2. Provide means for insuring a thorough mixture of air (particularly in the case of blow-through type systems).

Since the fundamentals governing the application of controls to the conditioner unit are the same for Blast Heating Systems as they are for Tempering Systems it is unnecessary to review this phase in detail.

The necessity for the use of an additional controller to maintain room conditions does, however, give rise to definite problems which must be carefully analyzed:

Thermostat Location

It is frequently difficult to decide between a room-type thermostat and a return air controller for use as a pilot instrument on a blast heating system.

Return air controllers are frequently chosen in preference to room thermostats because of reduced installation cost. Since the return air controller is generally located closer to the other control equipment, the cost of installation is reduced and this point is often the determining factor in the selection.

In general the return air control gives a more average measurement of the temperature throughout the space because the return air is commonly drawn from several different grilles throughout the system.

There are, however, other important factors which should be given full consideration in making the choice. These factors are:

1. Air distribution.
2. Return air ducts passing through cold or warm spaces.
3. Available location for room thermostat.

Air Distribution

Under certain conditions of distribution a room thermostat provides more satisfactory results than the return air control. Sluggish distribution, small air volume, stratification, or over capacity, may delay the ultimate response of the return air control sufficiently to introduce a "system lag" which would result in variations of temperature. These factors will also prove important in choosing a location for a room thermostat where used.

Return Air Ducts Passing Through Cold or Warm Spaces

If the return air duct shown should be passing through an area warmer than the room itself, the air temperature measured by the control bulb will not indicate true room conditions. Or, on the other hand, if the return air duct should be located on the outside wall of a building or in any cold space, the return air temperatures will be below space temperature.

It is thus possible that return air will not accurately indicate space temperatures as they exist. Further, the difference between the return air temperature at the unit and the space temperature will vary with the seasons of the year depending upon the degree of warmth or coldness surrounding the return duct.

Under such conditions a return air controller will not prove satisfactory since it will be inaccurate insofar as its reaction to changes within the space itself are concerned.

Available Room Thermostat Locations

A room-type thermostat inherently reflects changes in the temperature of air immediately surrounding it. It is therefore important that the thermostat location represent average conditions existing throughout the space.

When choosing a location for a room thermostat, the following factors should be taken into consideration:

1. Sun effect.
2. Path of air discharged from the grille.
3. Average conditions.
4. Pockets.
5. Walls receiving either heating or cooling effect from an extraneous source.

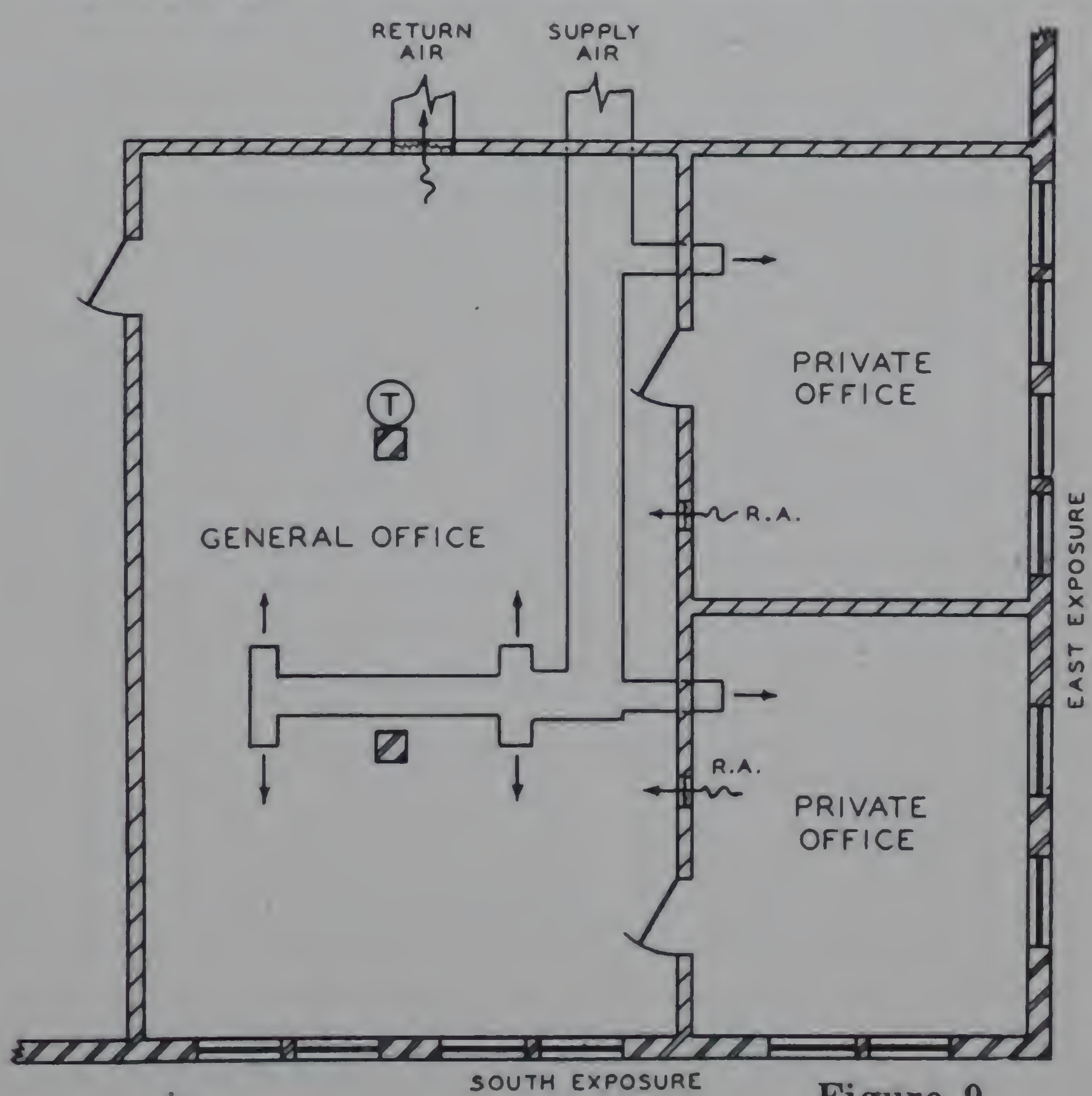


Figure 9

CONTROL OF CENTRAL FAN HEATING SYSTEMS

Fig. 9 illustrates a distribution system for two private offices and a general office located in the southeast corner of a building.

There is one supply grille for each private office, and a duct running across the general office discharging toward the windows and also toward the north for the rest of the general office. The returns for each private office are back into the general office, and the main return is located in the north end of the general office to return air to the conditioner.

The following factors must be considered in choosing the proper thermostat location:

Sun Effect

Direct rays of the sun will naturally effect the temperature of air around the thermostat. The thermostat should not be placed on any surface subject to the direct rays of the sun.

Path of Discharged Air

If a thermostat is in the path of discharged air, it will control from changes in this medium rather than room conditions. Particular care should be taken to prevent discharged air from striking the thermostat directly.

Average Conditions

The thermostat location should reflect average conditions in the space as nearly as possible. For this reason, either of the private offices shown in Fig. 9 would probably prove unsatisfactory. These spaces are comparatively small, and the occupancy factor is usually low. However, meetings might be held which would change the general condition in these private offices without effecting the remainder of the conditioned area.

The general office is most apt to have the general average of occupancy, lighting load, etc. For this particular application it would apparently be advisable to locate the thermostat somewhere in the general office where it would govern the comfort of the greatest number of people.

In choosing an average condition, consideration should always be given to:

1. Occupancy.
2. Exposure.
3. Proportion of the total area conditioned.

A thermostat located at "T" on the northerly pillar in the general office space should fulfill all of the requirements outlined above.

Pockets

Thermostats should be placed where they will be in the flow of moving air traveling through the room at a normal rate. Thermostats should not be located in corners as there is very little air movement at such points.

Walls with Extraneous Heat Source

Outside walls will usually be at a different temperature than the space, due to normal heat transfer between them and the atmosphere. Outside walls are therefore unsatisfactory for thermostat locations. Inside walls are generally satisfactory unless the location chosen is adjacent to steam or hot water pipes or warm air ducts. Heat from these pipes or ducts will affect the thermostat action.

OUTDOOR AIR CONTROL

Outdoor air may be used in conditioning systems for the following reasons:

1. Ventilation.
2. Elimination of odors.
3. To raise static pressure and eliminate infiltration.
4. Atmospheric cooling.

Many systems must provide cooling during the winter months, and wherever practical, cool outdoor air should be used for this purpose rather than mechanical cooling.

The control of outdoor air dampers may be made to provide any or all of the following functions:

1. Closure of outdoor air damper on fan shutdown. This is advantageous as it prevents unnecessary cooling of the building. It also reduces the possibility of uncomfortable drafts or freezing of mechanical apparatus.
2. Manually adjustable quantity of outdoor air. This may be required to allow for variations in ventilation requirements.
3. Atmospheric cooling. Controls may be arranged to automatically increase the percentage of outdoor air taken into the system to provide atmospheric cooling when the conditioned space becomes overheated.
4. Summer control of outdoor air. When outdoor air temperatures rise too high to be of any use for cooling purposes, only the minimum quantity needed for ventilation should be taken into the system.

PULL THROUGH SYSTEMS

Fixed Quantity of Outdoor Air

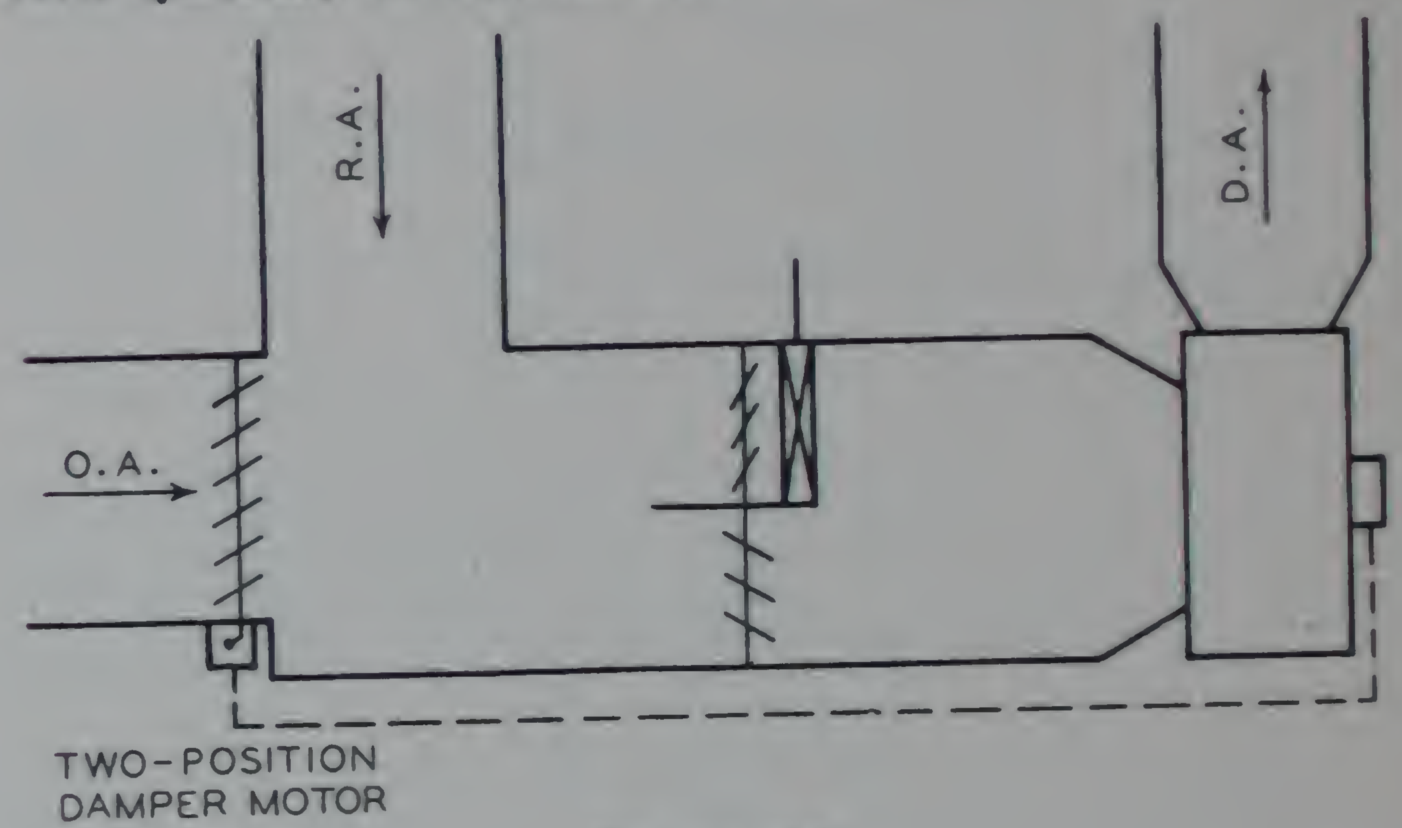


Figure 10

Fig. 10 illustrates a system wherein a fixed percentage of outdoor air is desired whenever the system is in operation.

A two-position damper motor is so interconnected with the fan motor circuit that it will open the outdoor air damper whenever the fan is operating and close it whenever the fan is stopped.

If the percentage of outdoor air is properly calculated, this system will provide protection against:

1. Unnecessary cooling of the building.
2. Cold drafts.
3. Freezing equipment.

Manually Adjustable Quantity of Outdoor Air

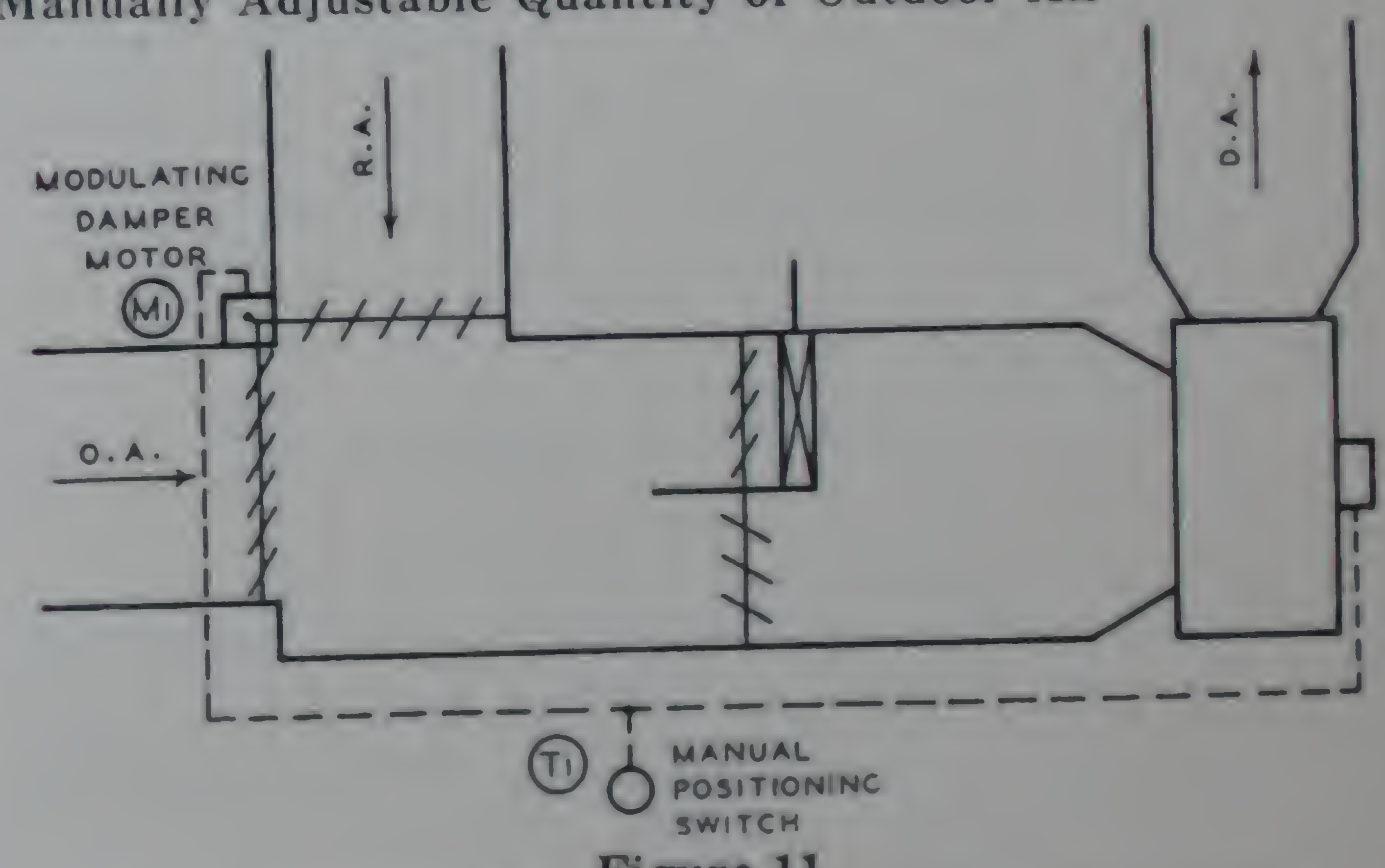


Figure 11

Fig. 11 illustrates an outdoor air control system which provides:

1. Damper closure on fan shutdown.
2. Manually adjustable quantity of outdoor air.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

Modulating damper motor M_1 is so interconnected with the fan motor circuit that it will close the damper whenever the fan stops and will open it to the position determined by the manual positioning switch whenever the fan is started.

The manual positioning switch may be set as desired for any percentage of outdoor air, and may be located at a remote point for convenient operation.

This type of system is often utilized for spaces with a variable occupancy factor so that the amount of air for ventilation may be changed with the requirements.

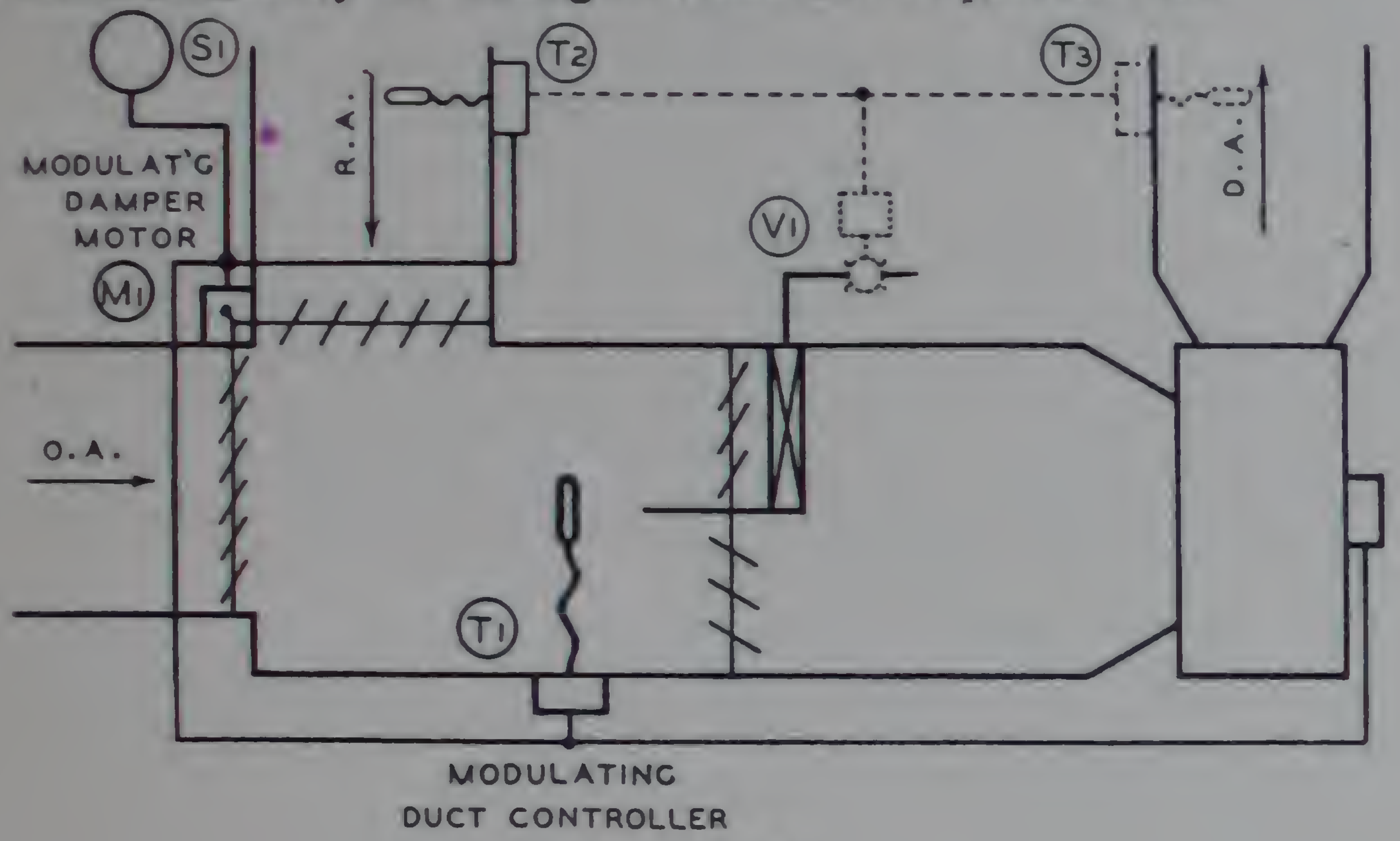


Figure 12

Mixed Air Control of Outside Air Dampers

Figure 12 illustrates a system of outside air control wherein the outside air is maintained at a minimum except during periods when an overheating condition exists. At such times the outside air is controlled by a thermostat located in the mixture of outside and return air so as to provide a constant temperature entering the heating coil.

In a system of this type, it is extremely difficult, due to air stratification, to find a location for the control bulb which will measure the average mixed temperature of outdoor and return air. Normally, the outdoor air will follow one section of the duct and the return air another. Also, as the dampers close, the condition of stratification changes. It is thus practically impossible to get an average temperature reading through any means, due to the constantly changing conditions. Sometimes this can be done through the use of properly placed baffles. Unless there is definite assurance that stratification will not exist and that a representative temperature measurement can be made, the use of this system is not recommended.

The sequence of operation is as follows:

1. The return air controller T_2 normally controls the steam valve V_1 to maintain the space temperature constant. Discharge controller T_3, acting as a low limit control, prevents the discharge air temperature from falling below the desired point, and will operate to keep the valve V_1 open sufficiently to maintain this temperature at the proper point.
2. When an overheated condition exists, the return air temperature will rise, and controller T_2 will act to place the controller motor M_1 under the command of the mixture thermostat T_1. The mixture thermostat, providing it obtains an average measurement of temperature, will position the outside and return air dampers to maintain a constant temperature of air entering the coil.
3. Whenever the fan shuts down, the return air damper motor M_1 acts to position the outside air damper to a fully closed position.

Outside Air Control of Dampers

All of the functions of outdoor air control may be accomplished through the use of "Economizer" type systems. This arrangement may be used on either pull-through or blow-through units.

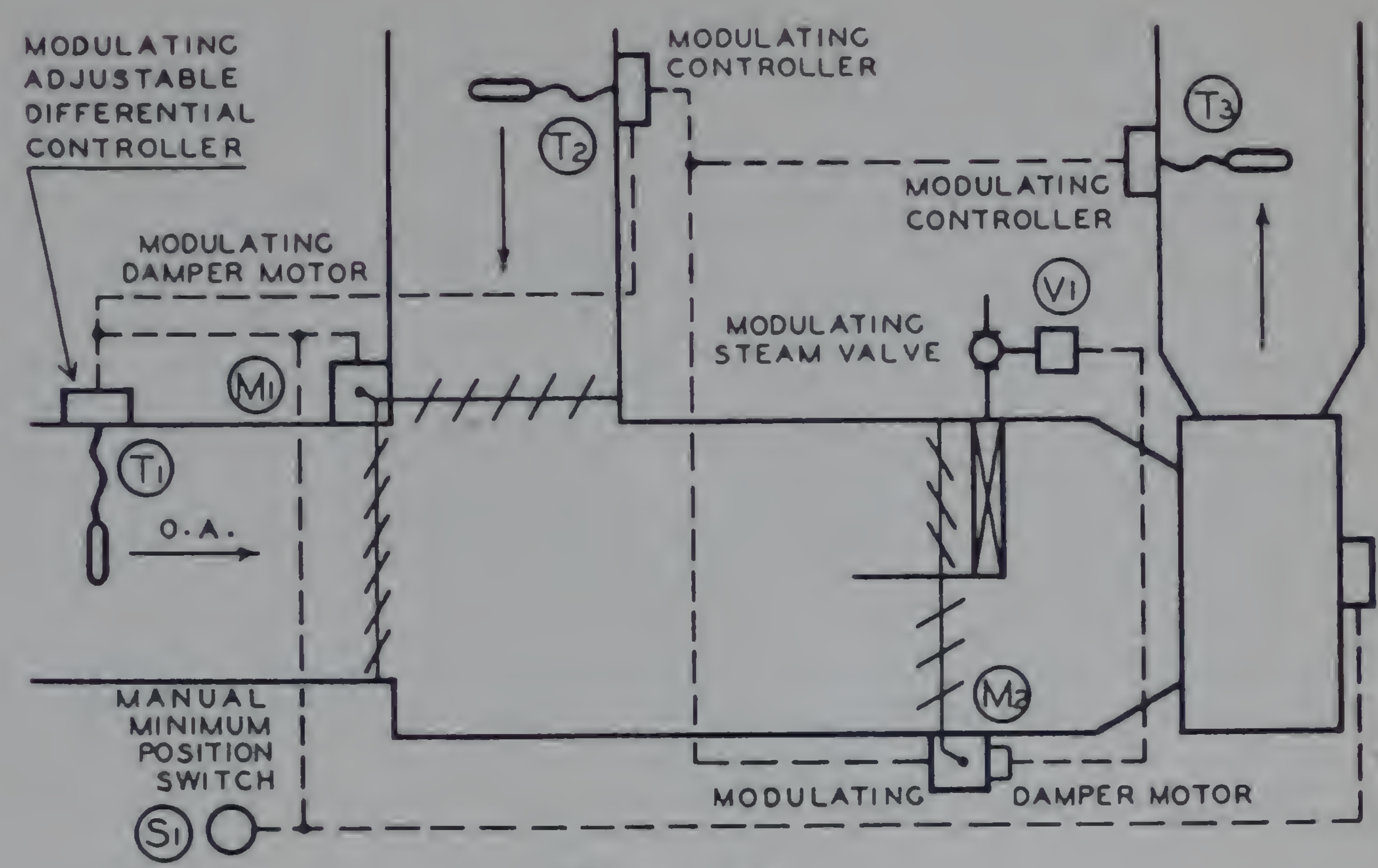


Figure 13

Fig. 13 illustrates a complete Economizer control system for winter control of outdoor air. Provisions have been made for:

1. Closing the outdoor air damper when the fan stops.
2. A manually adjustable minimum quantity of outdoor air when the fan is in operation.
3. Use of additional outdoor air for atmospheric cooling when required.

For purposes of illustration, a heating coil with face and by-pass damper has been shown. Any other method of providing heat may be used with this system.

The sequence of operation is as follows:

1. When the fan is inoperative, the outdoor air damper is automatically run to the closed position.
2. During the pick-up period, with the fan running, the outdoor air damper opens to a minimum position which may be manually adjusted by the minimum position switch S_1. This switch may be located at any remote point desired for easy adjustment.
3. The steam valve will be modulated to provide the necessary amount of reheat called for by the modulating return air controller T_2.
4. As the return air temperature rises, the return air controller T_2 will gradually throttle the steam valve and open the by-pass damper to provide less heat to the space.
5. Should the return air temperature become satisfied and thus call for a closed steam valve, the discharge controller T_3 will modulate the valve, and the face and by-pass dampers to provide just enough steam to maintain a minimum discharge temperature of, say, 65°. This temperature should be sufficiently low to provide cooling when required.

If, however, the mixture of minimum outdoor air as determined by the manual minimum position switch S_1 and return air should be at 65° or more, the modulating controller in the fan discharge T_3 will then allow the steam valve to close tightly.

6. If the return air temperature rises no further, the system will then operate with the outdoor air damper at its minimum position and with all steam shut off.
7. If the internal heat in the space increases sufficiently to cause overheating, the outdoor air damper motor M_1 will be operated at the command of the adjustable differential modulating outdoor air controller T_1.
8. This controller is adjusted to gradually open the outdoor air damper on a rise in outdoor air temperatures, and to return it to the minimum position at whatever outdoor air will provide a discharge air temperature of 65°, with the minimum quantity being provided.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

For example, in a system designed for a 20% quantity of minimum outdoor air, and with return air at 74°, the mixture of outdoor and return air would be at 65° when the outdoor air temperature reached 29° above zero. However, as the temperature rises above 29°, it is necessary to use more than a minimum amount of outside air if a 65° discharge is to be maintained.

For this condition, the adjustable differential outdoor air controller T_1 would be set to have the outdoor air damper wide open at 65° and would gradually close it to the minimum open position as the outdoor air temperature falls from 65° to 29° above zero.

So long as the return air temperature does not indicate an overheated condition, the outdoor air damper will be held in the minimum opening as dictated by the manual minimum position switch S_1.

9. If the space temperature should cool down due to the temperature of the discharge air provided, the return air controller would sense this change and take command of the outdoor air damper away from the outdoor air temperature controller T_1 and revert it to the minimum position switch S_1.

Discharge Air Control of Outside Air Dampers

Figure 14 illustrates a system of outside air control whereby additional outside air is provided whenever the return air controller, T_1, indicates the need for cooling. With this system, the discharge air controller, T_2, will take control of the outside air dampers, and will provide air at a temperature which will furnish the required cooling whenever the space overheats, as indicated by temperature controller T_1.

This system provides for a manually adjustable minimum quantity of fresh air, whenever the fan is in operation.

The sequence of operation is as follows:

1. Controller T_1 normally will position steam valve V_1 in accordance with the heat demands of the space. Controller T_2, located in the discharge air, will prevent the discharging of too cool air.

2. As the return-air temperature rises, controller T_1 will throttle valve V_1 toward the closed position. If the temperature in the return air continues to rise and the minimum position of the outside air damper is set so that the discharge air will not drop below the setting of controller T_2, valve V_1 will go to the completely closed position, making a contact in its auxiliary switch.

3. On a further rise in return air temperature, T_1 will make a circuit through its auxiliary contacts, thereby energizing the changeover relay. The changeover relay, in its energized position, will place the control of outdoor air damper motor M_1 under the control of discharge controller T_2. The controller T_2 will then modulate the position of the outside air dampers to maintain the discharge air at the setting of the controller T_2.

Controller T_2 is set for a low enough temperature to provide the space with the necessary cooling.

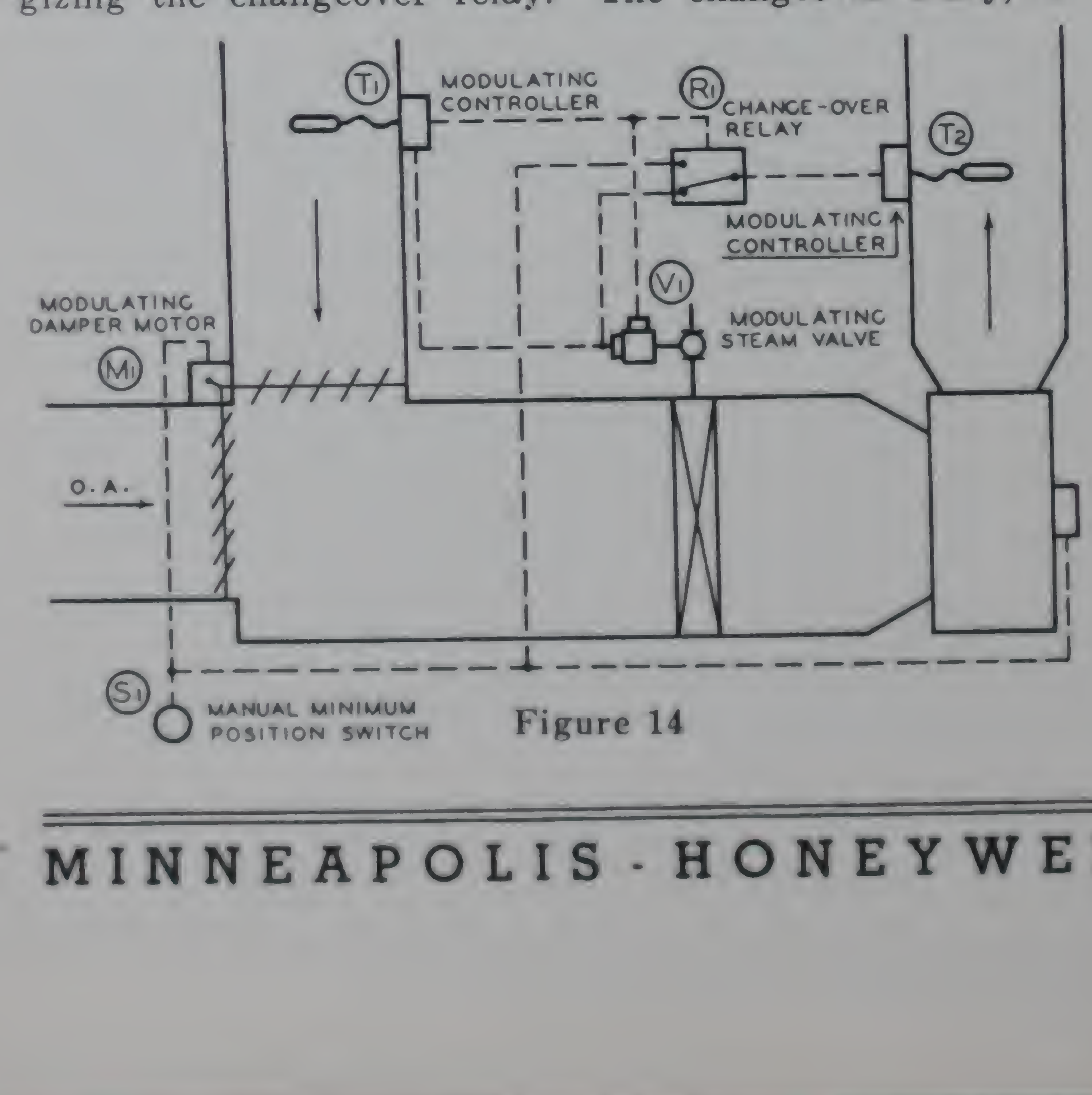


Figure 14

Direct Outside Air Control Systems

Figure 15 illustrates a system of control in which admittance of outside air is determined by return air or room thermostat to provide for recirculation only during pickup periods, fixed minimum quantity of outside air during normal heating periods, and additional outside air for atmospheric cooling when an overheated condition exists.

The sequence of operation is as follows:

1. T_1 normally positions motorized valve V_1 to maintain constant space temperature. When the return air temperature is low, as during a pickup period, valve V_1 will be wide open, and controller T_1 will have outside air damper motor M_1 closed to provide maximum capacity for picking up the temperature.

2. As the return air temperature rises, controller T_1 first positions outside air damper motor M_1 to provide a minimum introduction of outside air, as determined by minimum position switch S_1.

3. As the return air temperature continues to rise, return air controller modulates valve V_1 to maintain the space temperature constant. During such periods, if valve V_1 should close sufficiently to cause the discharge temperature to drop below the setting of low limit control T_2, controller T_2 will open the valve sufficiently to maintain constant temperature in the discharge, thus preventing cold drafts.

4. Should the return air temperature rise above the normal control point, indicating that an overheated condition exists, valve V_1 will tend to close off, cutting off the supply of steam to the coil. At this point, outside air damper motor M_1 will be modulated toward an open position, introducing an additional quantity of outside air to accomplish the necessary cooling.

It will be noted in this system that additional outside air for cooling is admitted only at times when the steam supply to the coil is being throttled off. Therefore, the system does provide an advantage in economy of operation. This system should not be used where there is danger of freezing up the coil.

A system of this type is very commonly used for control of auditorium unit ventilators and on smaller blast heating systems.

See page 22 of Section Three for electrical wiring.

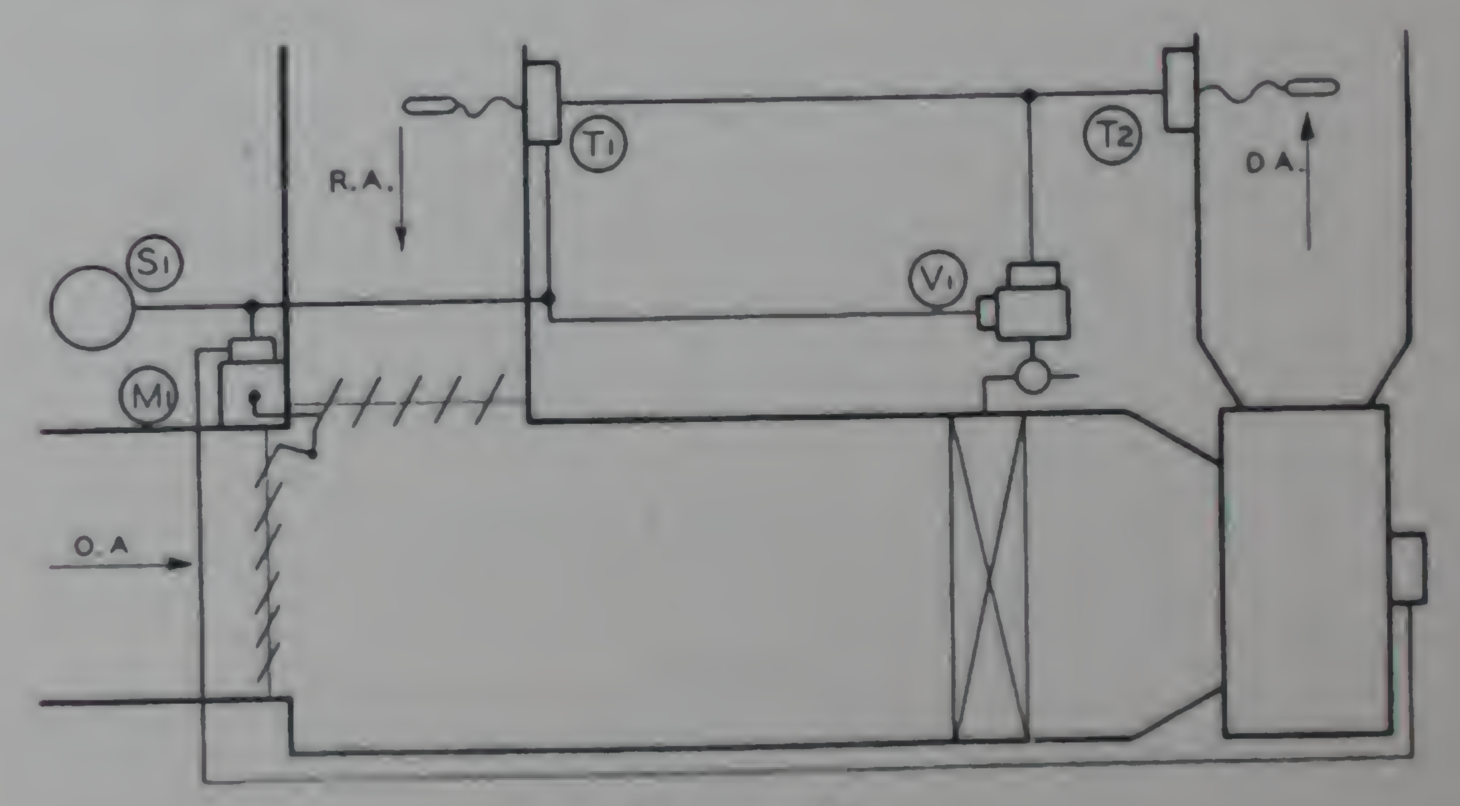


Figure 15

CONTROL OF CENTRAL FAN HEATING SYSTEMS

BLOW-THROUGH SYSTEMS

The discussion so far has covered the introduction of outside air into systems of the draw-through fan variety. Due to the nature of the blow-through system, the problems accompanying the admission of outside air are much more simple since the outside and return air is thoroughly mixed in passing through the fan. It is therefore possible to get a very good average reading of the temperature of the mixed air by locating a duct thermostat downstream from the fan and using this thermostat for positioning the outside air damper according to the principles outlined on the systems described previously.

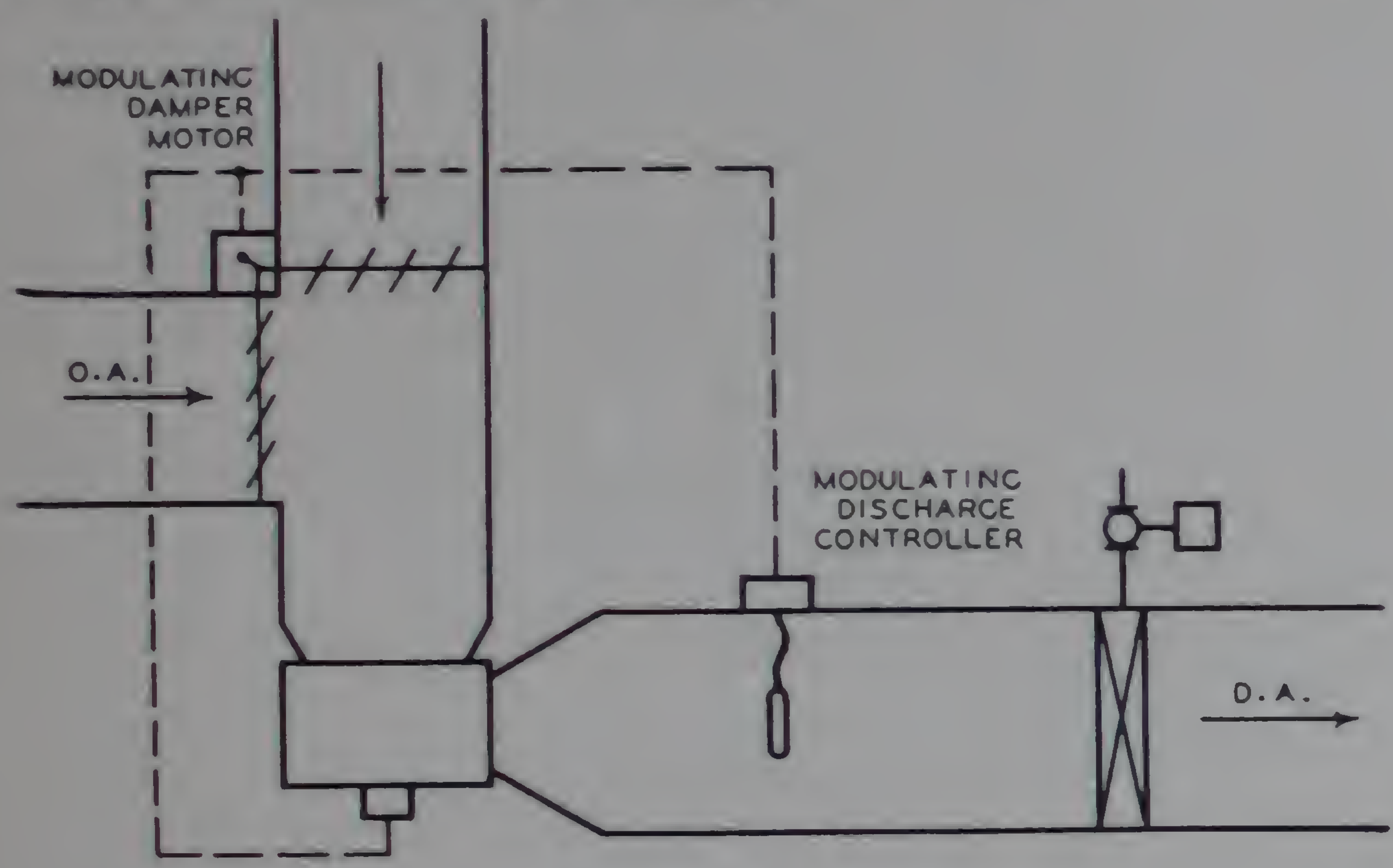


Figure 16

Fig. 16 illustrates outdoor air control with a blow-through fan system and provides:

1. Outdoor air damper closure on fan shutdown.
2. Constant temp. of mixed outdoor and return air.
3. No fixed minimum amount of outdoor air.

Modulating damper motor is so interconnected with the fan circuit that it will close tight whenever the fan is stopped.

When the fan is running, the modulating discharge controller operates the motor to position the outdoor and return air dampers so as to give a constant discharge air temperature of 60° or 65°. Thus air at a temperature low enough to provide atmospheric cooling is always available if needed.

Though no fixed minimum of outdoor air is provided, if the discharge controller is set for 60°, it will require approximately 14% of outdoor air at zero to mix with return air at 70° to maintain the 60° discharge air temperature. This is often a sufficient quantity of outdoor air for ventilation, and consequently no minimum need be used for those systems.

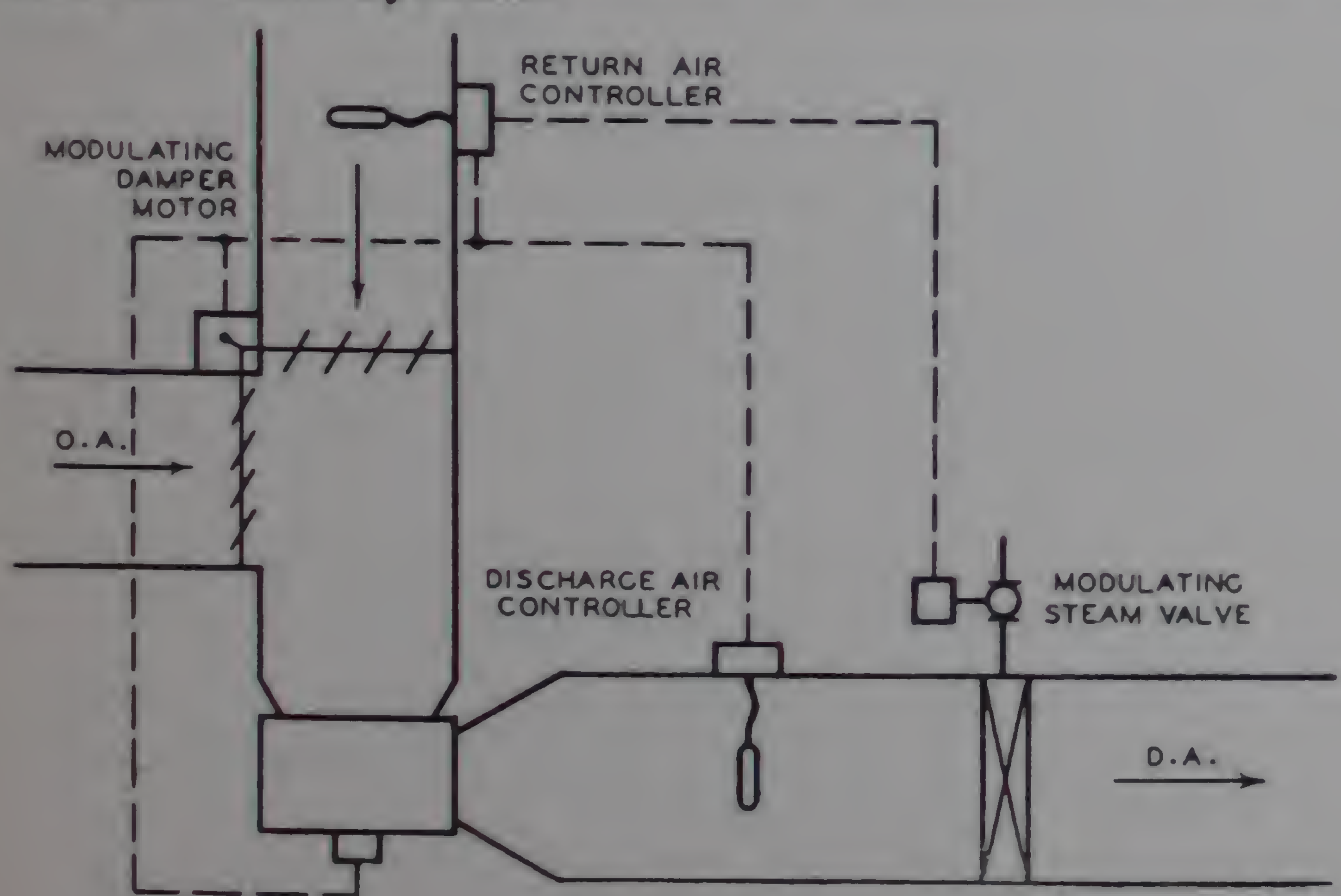


Figure 17

This system does not provide full economy, since it takes more than the quantity of outdoor air required for ventilation in all but the coldest weather.

Fig. 17 illustrates a system similar to that shown in Fig. 16, excepting that provisions have been made to keep the outdoor air damper closed until the return air temperature has risen to the setting desired in the space being controlled. This provides additional economy of operation.

It may be accomplished either by an additional mechanism within the return air thermostat or by means of a connection to the steam valve which will not allow the outdoor air damper to operate at the command of the discharge air controller until the steam valve has been throttled.

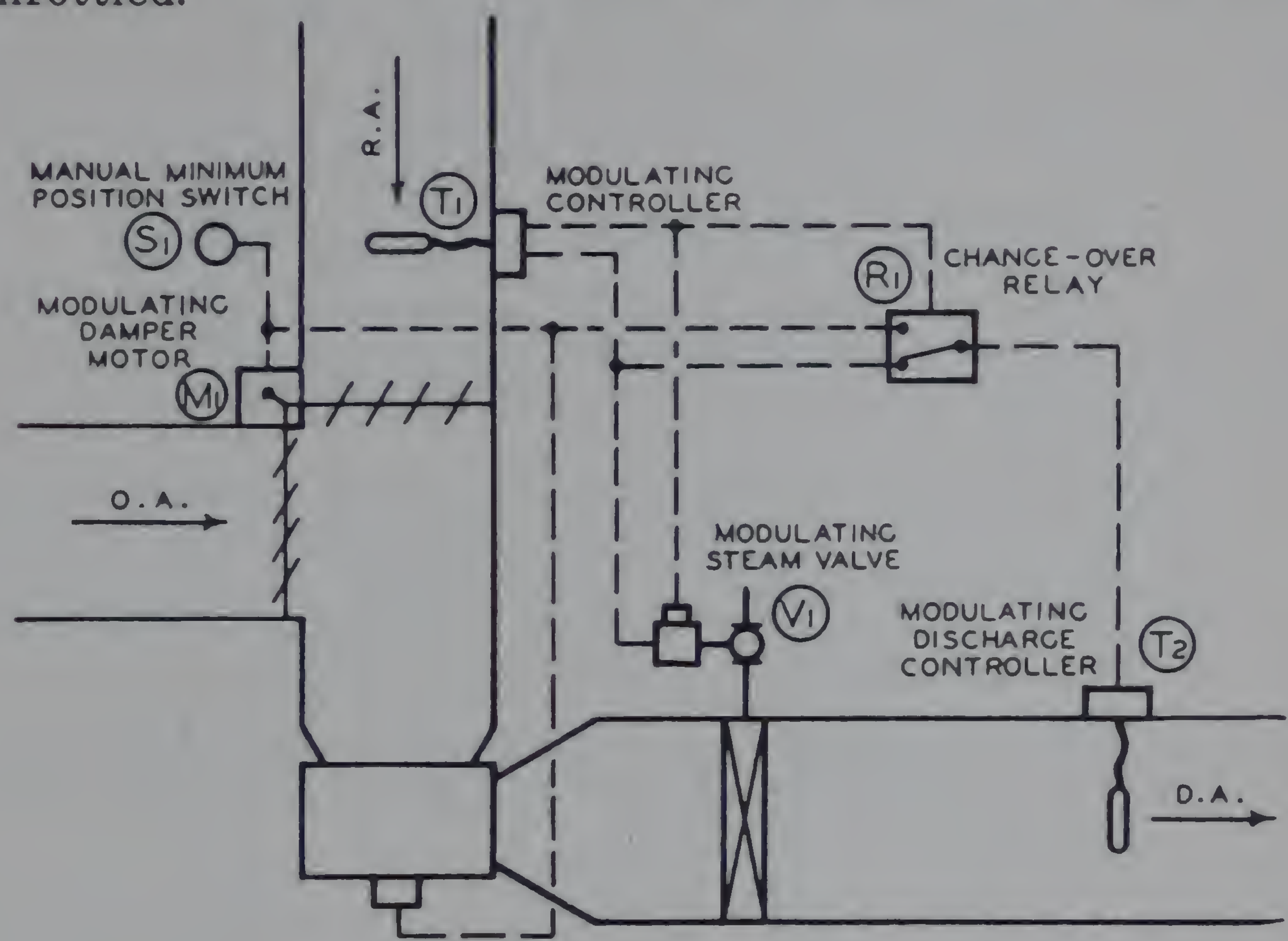


Figure 18

Fig. 18 illustrates an Economizer system applied to a blow-through fan unit. The sequence of operation and effect of this application is similar to that shown for Fig. 14, the only difference being found in the physical arrangement of equipment.

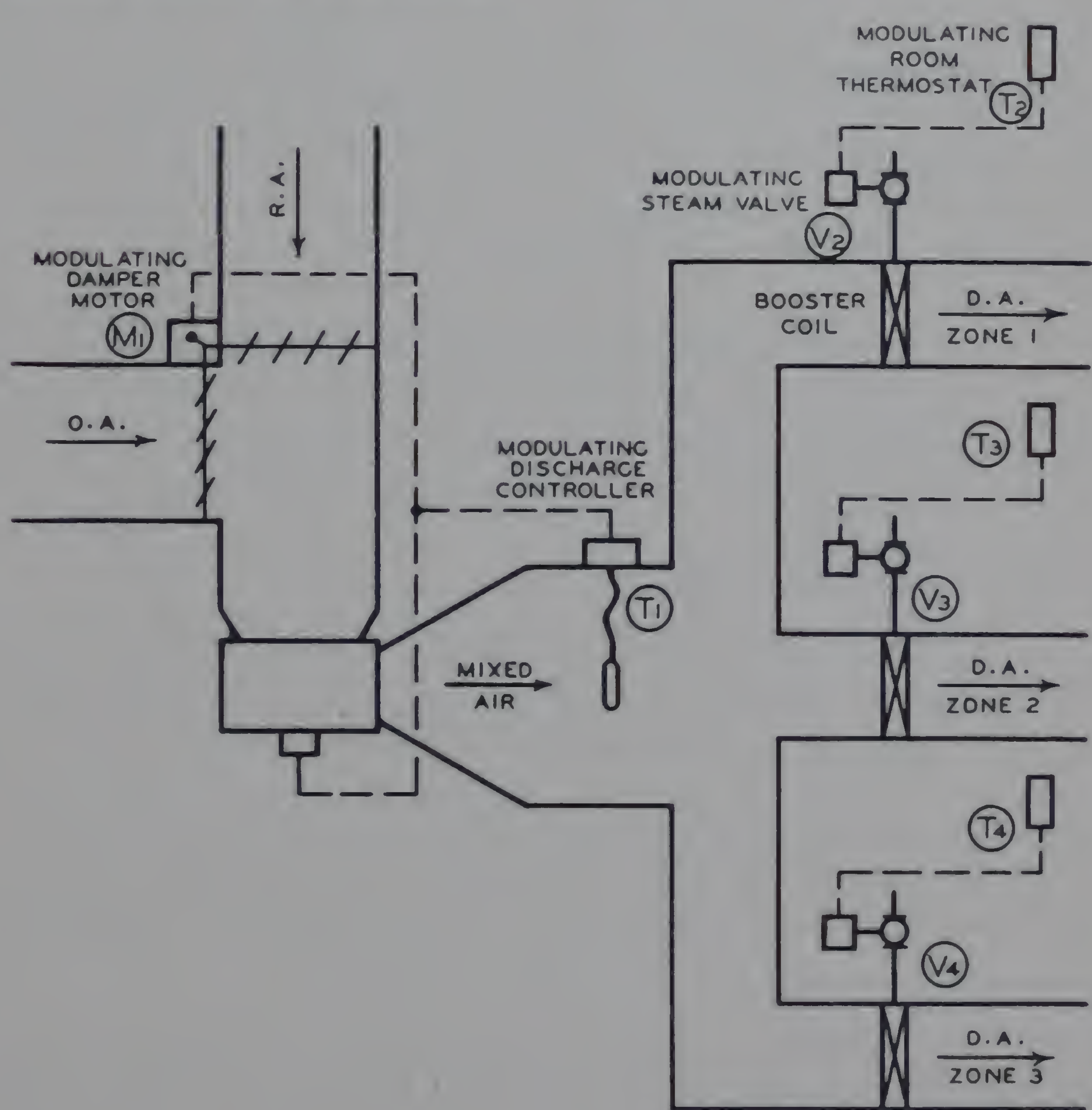


Figure 19

CONTROL OF CENTRAL FAN HEATING SYSTEMS

Fig. 19 illustrates a blow-through fan application for zone control where the mixture of outdoor and return air is kept at a temperature low enough to provide cooling to any zone when required.

1. The modulating discharge controller T_1 operates the outdoor and return air dampers to maintain a discharge temperature of 60°.
2. The outdoor air damper motor is arranged to close whenever the fan is stopped. In each zone duct a booster coil supplies the amount of reheat necessary to maintain space conditions. A modulating room thermostat operates a modulating valve on each booster coil.

Should any zone become overheated, its booster coil valve will close and allow the discharge of tempered air at 60° or 65° for cooling purposes.

PRE-HEATER FRESH AIR CONTROL

Where it is necessary to use pre-heat coils there are two factors which should always be considered from the control standpoint.

1. **Coil Capacity.** It is desirable that the control of the pre-heat coils be so arranged that it will always be possible to obtain low temperature discharge air for cooling. In some cases the operation of a full-size pre-heat coil may raise the mixed air temperature so high that cooling cannot be obtained.
2. **Freeze-Up Protection.** Control of the pre-heat coil should always be arranged so that there will be no danger of freezing these coils.

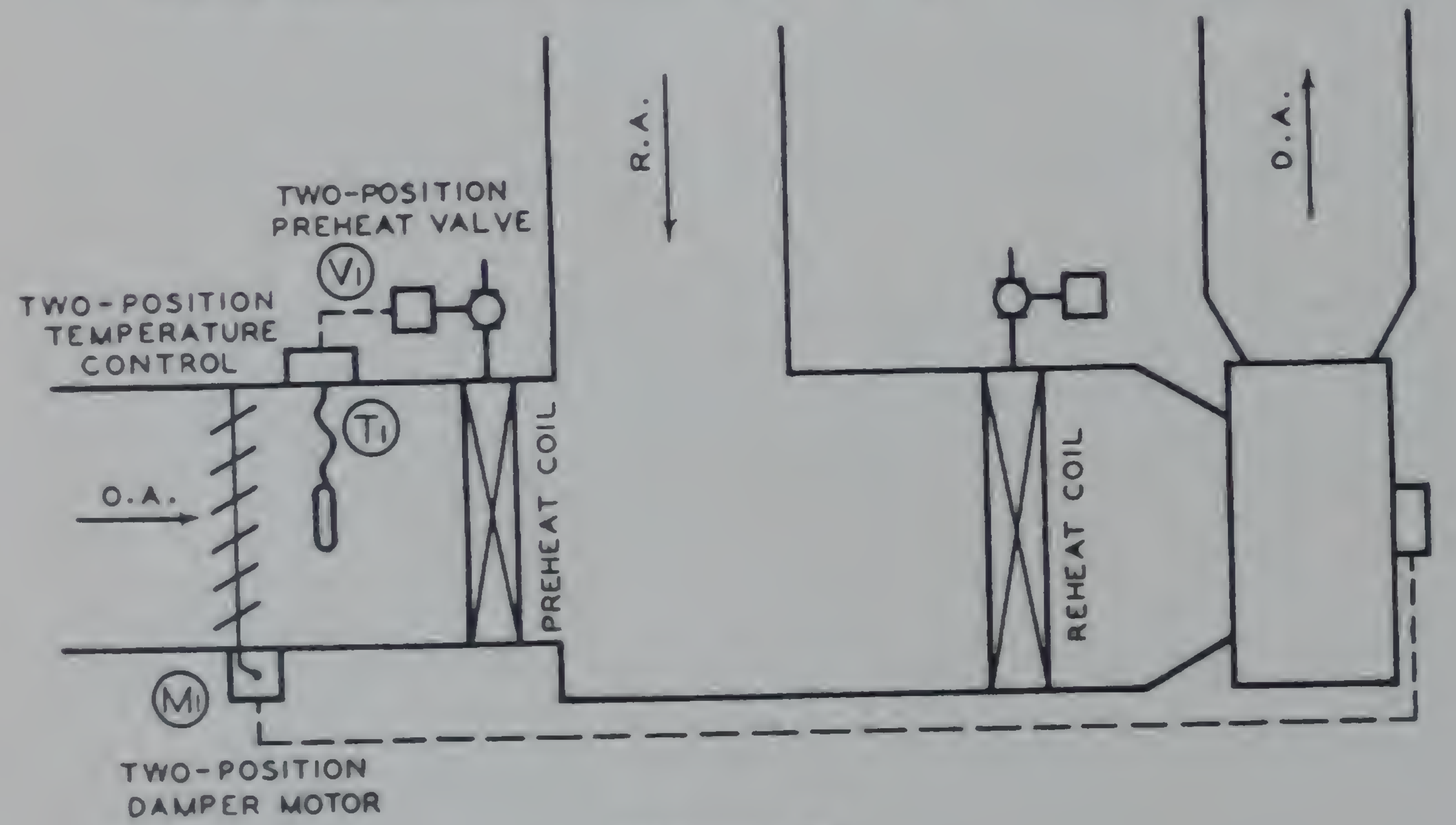


Figure 20

Fig. 20 illustrates a system using a single pre-heat coil controlled from outdoor air temperatures. It may be used for any fixed percentage of outdoor air up to 100%, in which case there will be no return air connection.

The system provides:

1. Outdoor air damper closure on fan shutdown.
2. Gradual opening of the pre-heat valve which would be wide open at 35° outside temperature.

The modulating temperature controller T_1 in the outdoor air is usually set so as to start opening the modulating pre-heat valve V_1 at about 38° and to have it wide open by 33° or 35°. The use of modulating control on the pre-heat coil eliminates sudden changes in discharge temperature due to its gradual action.

If the pre-heat coil has a pick-up capacity of more than 35°, it will be impossible to obtain discharge air for cooling purposes when outdoor air temperatures are above 25° or 30° above zero. This may result in overheating the conditioned space.

In some instances, where less than 100% outdoor air is used, it may be possible to keep the pre-heat coil closed until temperatures of about 20° or 25° above zero have been reached. This sometimes serves to prevent the possibility of discharge air temperatures too high to afford cooling if needed. When it is contemplated to set the pre-heat coil controller below the freezing point, two-position control must be used to minimize the possibility of freezing the coil during the opening of the pre-heat valve.

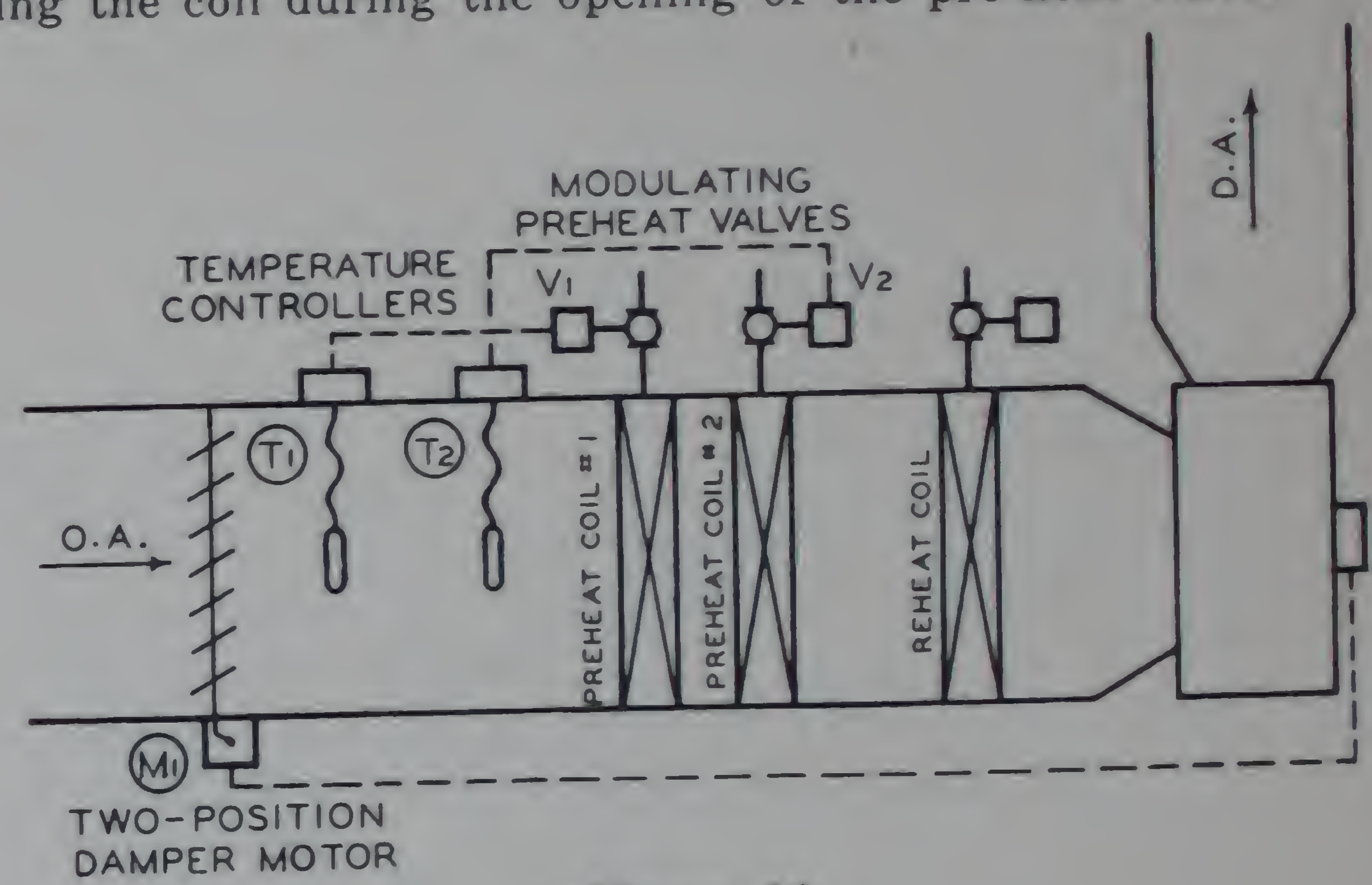


Figure 21

Where a large pre-heat capacity is required, a system as shown in Fig. 21 may be used. The system provides:

1. Closure of the outdoor air damper motor on fan shutdown.
2. Controls to open the pre-heat coil steam valve at predetermined temperature setting.

For purposes of illustration, assume that the system is taking in 100% outdoor air and is designed for —20°. Each of the pre-heat coils will have a pick-up capacity of 30°. The reheat valve is controlled by room conditions or discharge air temperature.

The sequence of operation is as follows:

1. Two-position damper motor M_1 opens the outdoor air damper when the fan is started and closes it whenever the fan is stopped.
2. The modulating outdoor controller T_1 operates the modulating steam valve V_1 to have it wide open above 32° above zero. With steam valve V_1 open, the temperature of air delivered to the reheat coil will be 62° when the entering air is 32°.
3. When the outdoor air temperature has dropped to 5° above zero, the temperature of air delivered to the reheat coil will be 35°. At this point modulating temperature controller T_2 will start to open the pre-heat valve V_2 and will have it wide open at zero degrees. The temperature of the air delivered to the reheat coils will then be 60°.

   At 20° below zero, the temperature of air delivered to the reheat coil will be 40° above zero.

   It is to be noted that pre-heat coil No. 1 must open before pre-heat coil No. 2 to prevent the possibility of freezing the No. 2 coil.

It is possible to obtain air in the discharge at a low enough point to provide cooling if needed.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

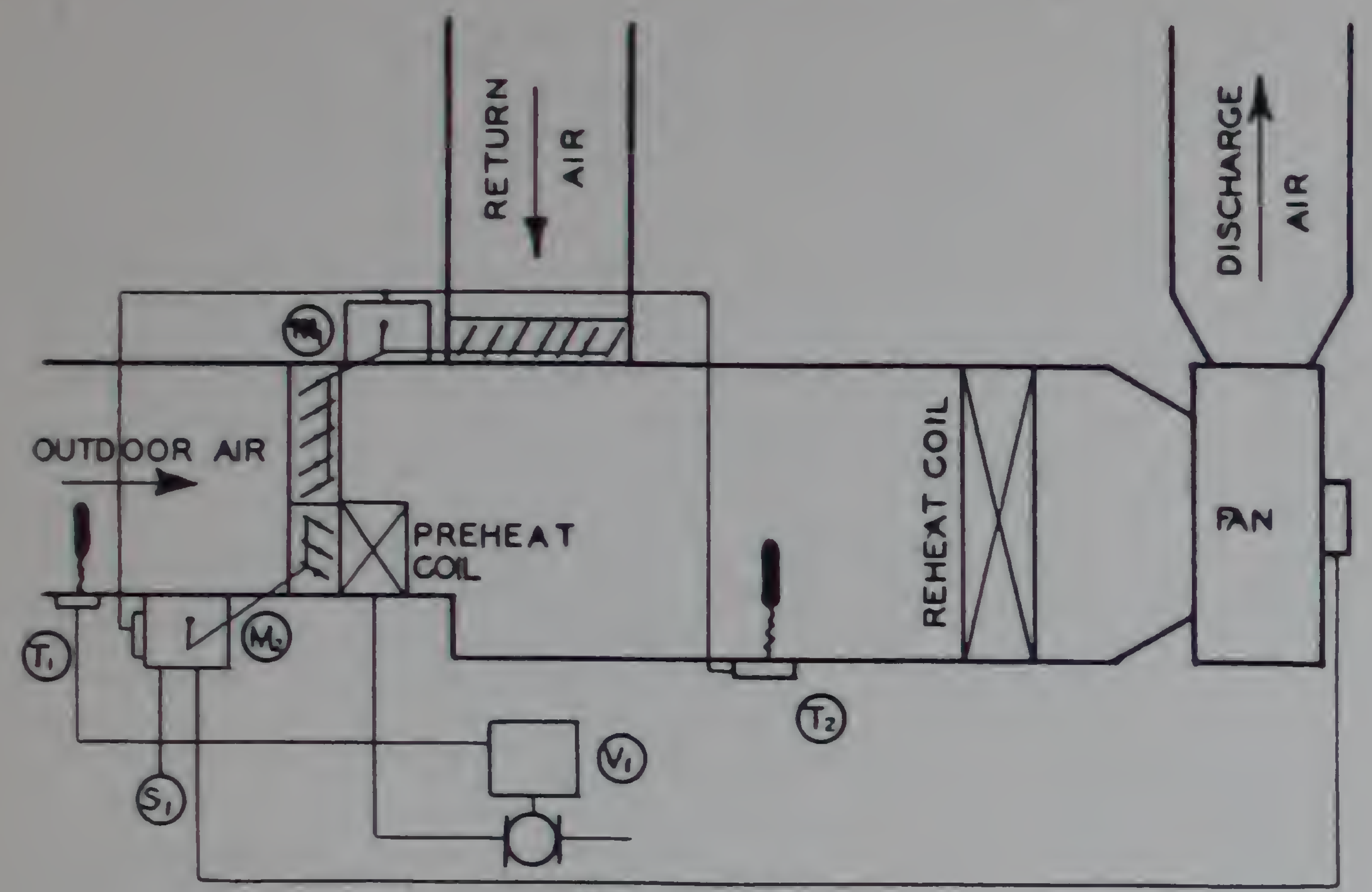


Figure 22

Fig. 22 illustrates a preheat coil with face and by-pass dampers arranged to provide:

1. Closing of face and by-pass dampers in the outdoor air duct on fan shutdown.
2. Manually adjustable minimum percentage of outdoor air.
3. A minimum temperature of mixed outdoor and return air.

The sequence of operation is as follows:

1. When the fan is started, the motor M2 on the outdoor air damper in front of the preheat coil opens to a minimum position, which is manually adjusted to any desired minimum by positioning switch S1.
2. Two-position temperature controller T1 in the outdoor air opens valve V1 on the preheat coil at temperatures of 35° or lower.
3. Modulating temperature controller T2 operates damper motor M1 to position the outdoor air damper around the preheat coil and the return air damper to maintain a mixed air temperature of 65°.
4. When the fan is shut down, motor M2 closes the outdoor air face damper, and an auxiliary switch on M2 operates motor M1 to close the outdoor air by-pass damper.

As explained under "Heating Coils Control," it is difficult to obtain a representative temperature of mixed air without properly baffling the duct-work. Usually stratification of pre-heated outdoor air, natural outdoor air, and return air will exist, thus making it difficult to measure true temperature.

When using a system as described above, proper consideration should be given to the location of the control bulb T_2.

If this system is used, it may not be necessary to have a low limit controller on the reheat coil, inasmuch as the mixed air temperature may be warm enough to prevent drafts.

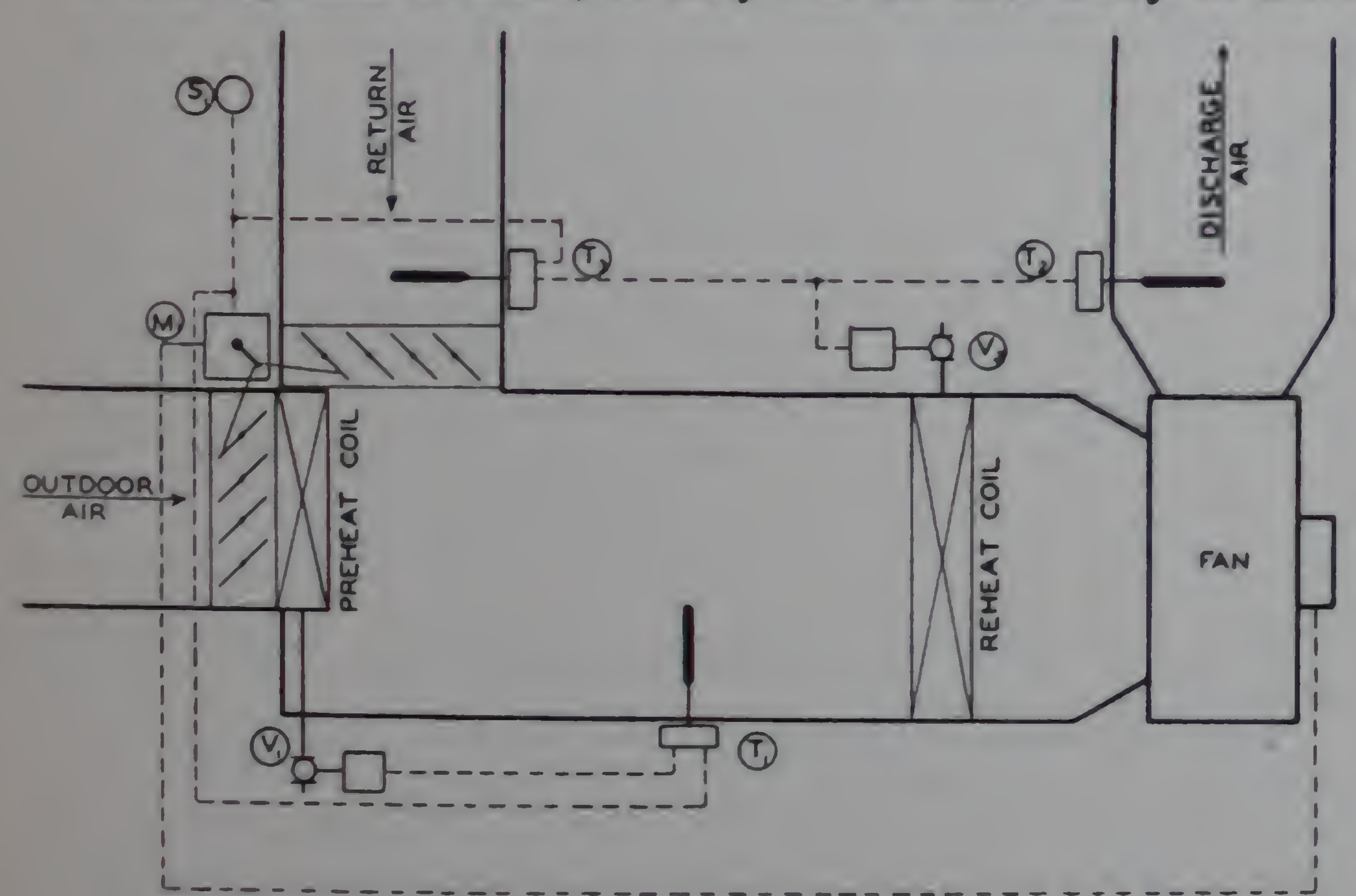


Figure 23

Economizer Control with Pre-Heat Coils

A type of heating surface is available on which the manufacturers' recommendations permit the modulation of steam when exposed to sub-freezing air. When this type of heating surface is used, it permits a somewhat simplified method of outside air control because ordinarily certain control sequences become necessary on a preheat coil application because the steam valve must be operated in a positive or two-position manner.

Fig. 23 illustrates a system of control for outside air dampers and preheat coil which will provide for the following:

1. Closing of outdoor air damper on fan shutdown.
2. Manually adjustable minimum percentage of outdoor air.
3. Additional outdoor air for atmospheric cooling when needed.
4. Modulation of temperature of outdoor air admitted.

It must be understood that the system described in Fig. 23 cannot be used unless the heating surface used for the preheat coil is recommended by the manufacturer for modulating service in tempering coil applications.

Sequence of operation is as follows:

1. When the fan is shut down, the outside air damper is automatically returned to the closed position.
2. When the fan is started, the outside air damper opens to a minimum position which is manually adjusted to any desired minimum by positioning switch S_1. This switch may be located at any remote point desired for easy operation.
3. Return air controller T_3 modulates the steam valve V_2 to maintain a constant space temperature. T_3 is shown as a return air controller. This may also be a room thermostat if desired.
4. The discharge controller T_2 acts as a low limit control and prevents the discharge of air at a temperature lower than the chosen control point.
5. As the return air temperature rises, steam valve V_2 throttles to a closed position or to the minimum determined by discharge low limit control T_2. If, due to high internal heat gain, the space overheats, the return air temperature will rise further and will transfer the control of outside air damper motor M_1 to controller T_1 located in the mixture of outside and return air. The outside air damper will then be modulated to maintain the predetermined temperature in the mixture (usually 60°).
6. Should the outside air temperature drop low enough to cause the temperature of the mixed outside and return air to drop below the control setting of thermostat T_1, this mixed air control would modulate the steam valve on the tempering coil V_1 so as to maintain the predetermined desired temperature. (It should be noted that danger of stratification may exist in the system as shown which would allow thermostat T_1 to measure a temperature not representative of the mixture. If such danger exists, extreme care should be used in properly baffling the outside and return air admission to provide a true mixture.)
7. As the space temperature drops, return air controller T_3 will again revert control of damper motor M_1 to the minimum position switch S_1. Under all conditions, of course, thermostat T_1 located in the mixture will control temperature coil valve V_1 to maintain a constant temperature in the mixture.

This system uses only a minimum quantity of outside air excepting at such times as additional outside air is needed for cooling purposes. In this way a maximum of economy is realized as unnecessary heating of outside air is eliminated.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

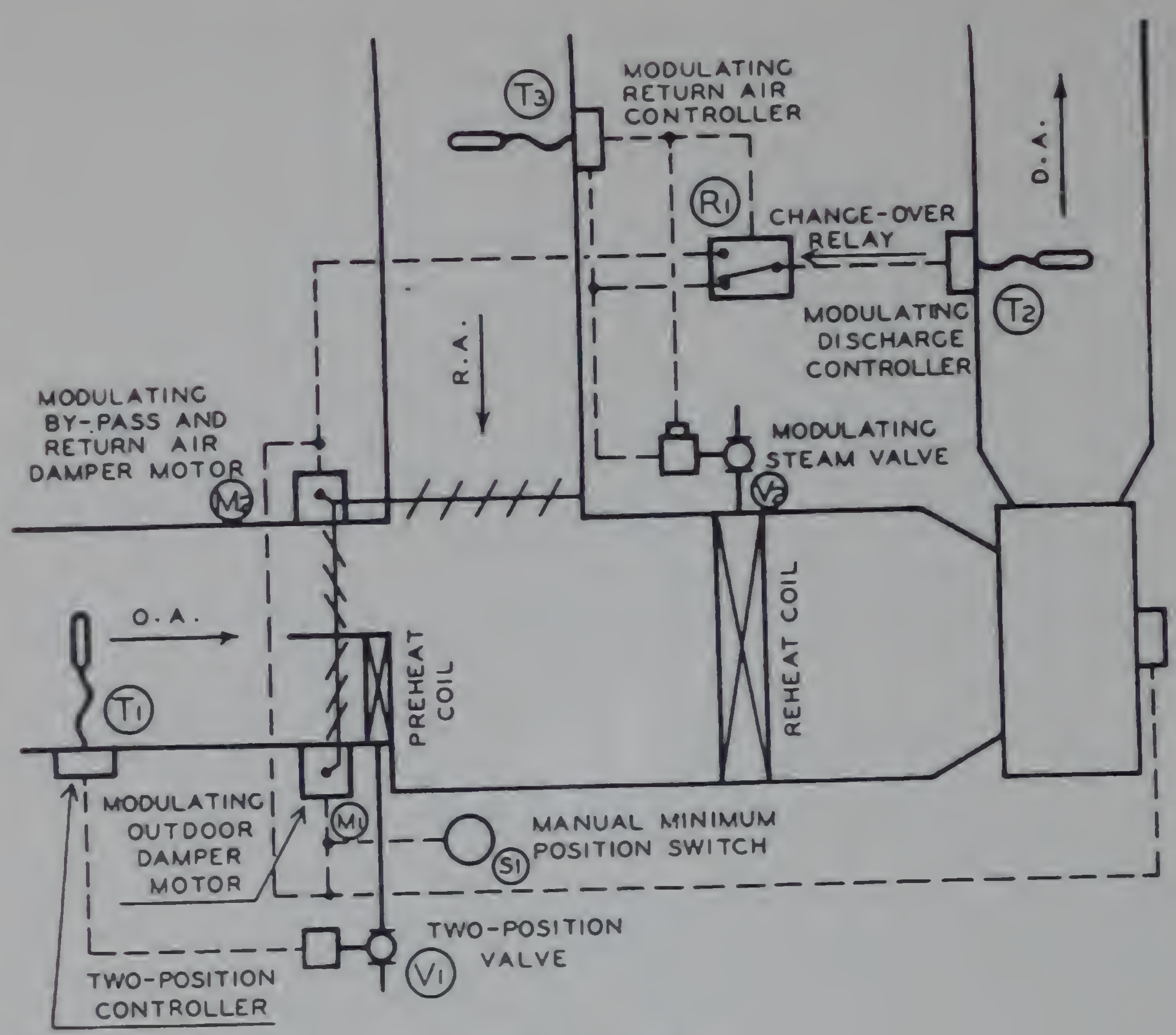


Figure 24

Fig. 24 illustrates another economizer control system in which a pre-heat coil with face and by-pass dampers is utilized. This system is similar to Fig. 14 except a pre-heat coil is used.

One difference in operating sequence between this and the previous system is found in the fact that mixed air temperatures are maintained by repositioning the pre-heater face and by-pass dampers rather than through modulation of the outside air damper.

WINTER HUMIDIFICATION

The following types of equipment are in general use for humidification:

1. **Water spray humidifier.**
2. **Pan type humidifier.**
3. **Steam jet humidifier.**
4. **Air washer system.**

Pan type humidifiers are somewhat limited in capacity and generally are used only where moisture requirements are low.

Steam jet humidifiers are used more commonly for industrial applications, and when used for comfort conditions, care must be taken to prevent objectionable odors from the liberation of boiler compound.

Water spray humidifiers are probably the most generally used for comfort conditioning work.

Where there is considerable humidification load, air washers may be used because of their greater capacity.

The water used in the washer or spray must be warm enough to vaporize and pass into the air stream.

The two common methods of heating the washer or spray water are:

1. **The use of a tempering coil before the washer.**
2. **The heat exchanger to heat the water before entering the washer.**

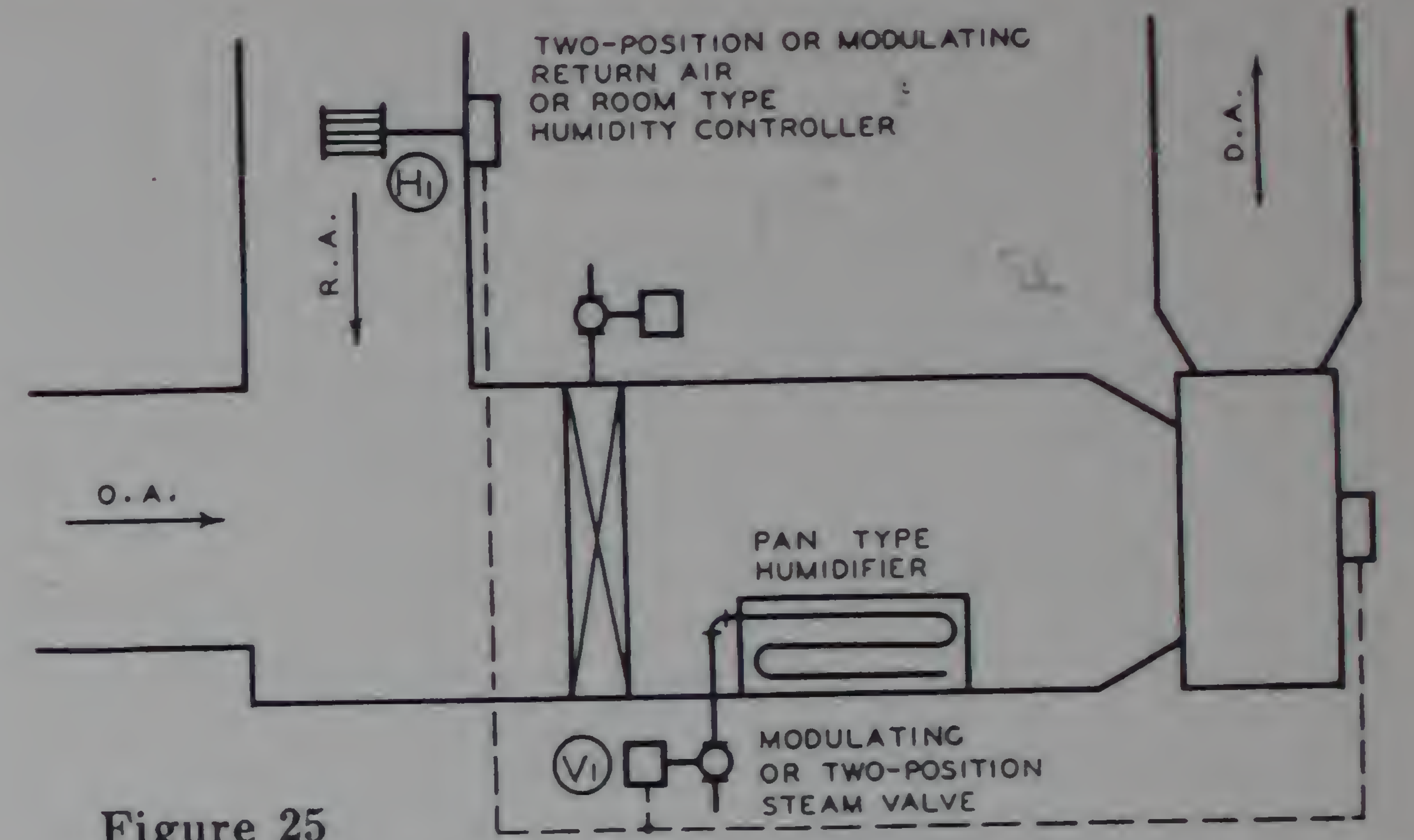


Figure 25

Fig. 25 illustrates a typical control application for a pan type humidifier. Either a two-position or modulating humidity controller H_1 operates a modulating or two-position steam valve V_1 on the steam line to the humidifier. As the humidity falls, the steam valve is opened to vaporize water and thus provide humidity.

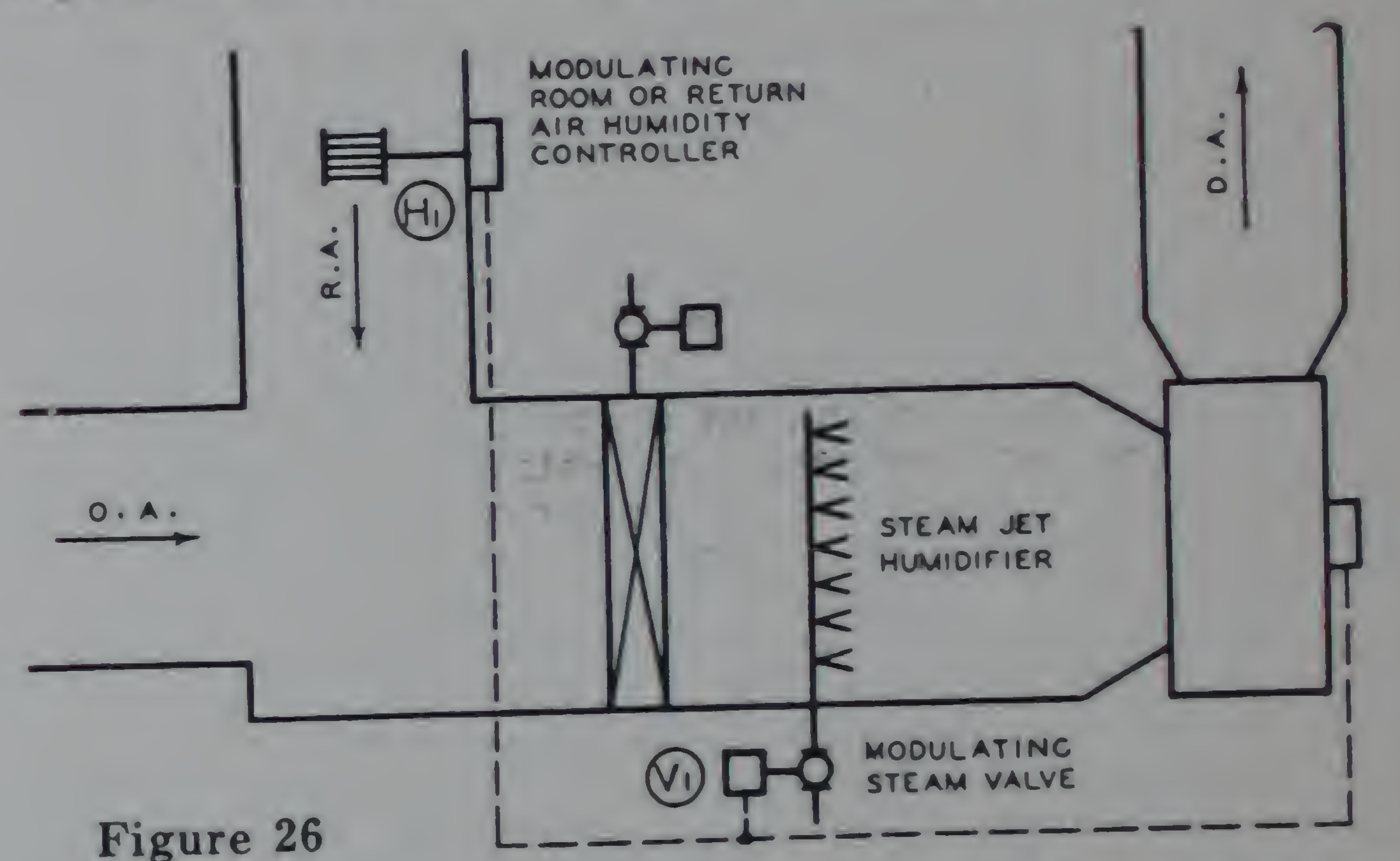


Figure 26

Fig. 26 illustrates a typical application for a steam jet humidifier. A modulating humidity controller H_1 operates a modulating steam valve V_1 to control the steam flow for humidification.

The valve is so interconnected with the fan motor circuit that it will be tight closed when the fan is stopped to prevent excessive moisture conditions.

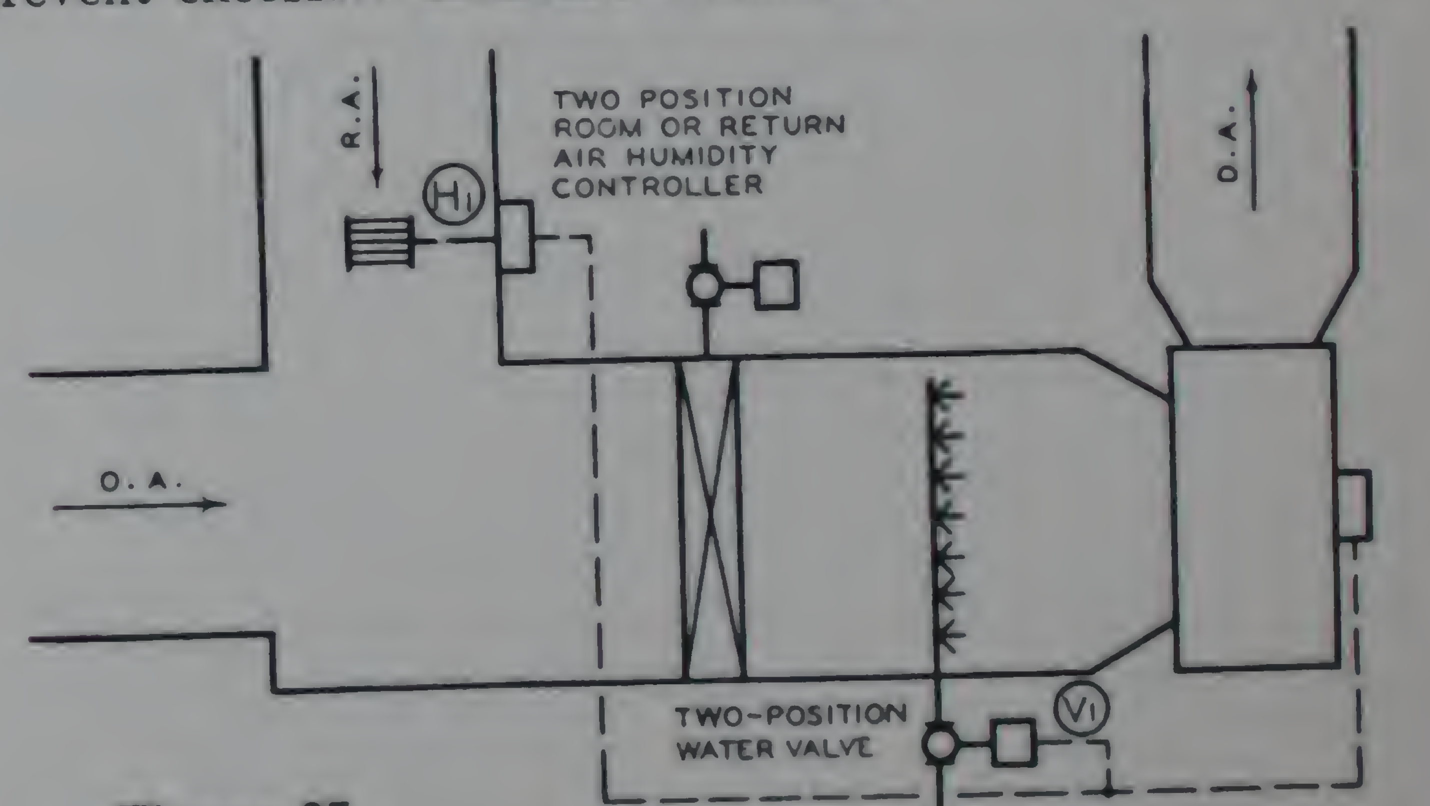


Figure 27

Fig. 27 illustrates an application for humidification using a water spray.

The two-position humidity controller H_1 operates a two-position water valve V_1.

The water valve is so interconnected with the fan motor that it will close tightly whenever the fan is stopped to prevent the possibility of excessive moisture conditions in the ductwork.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

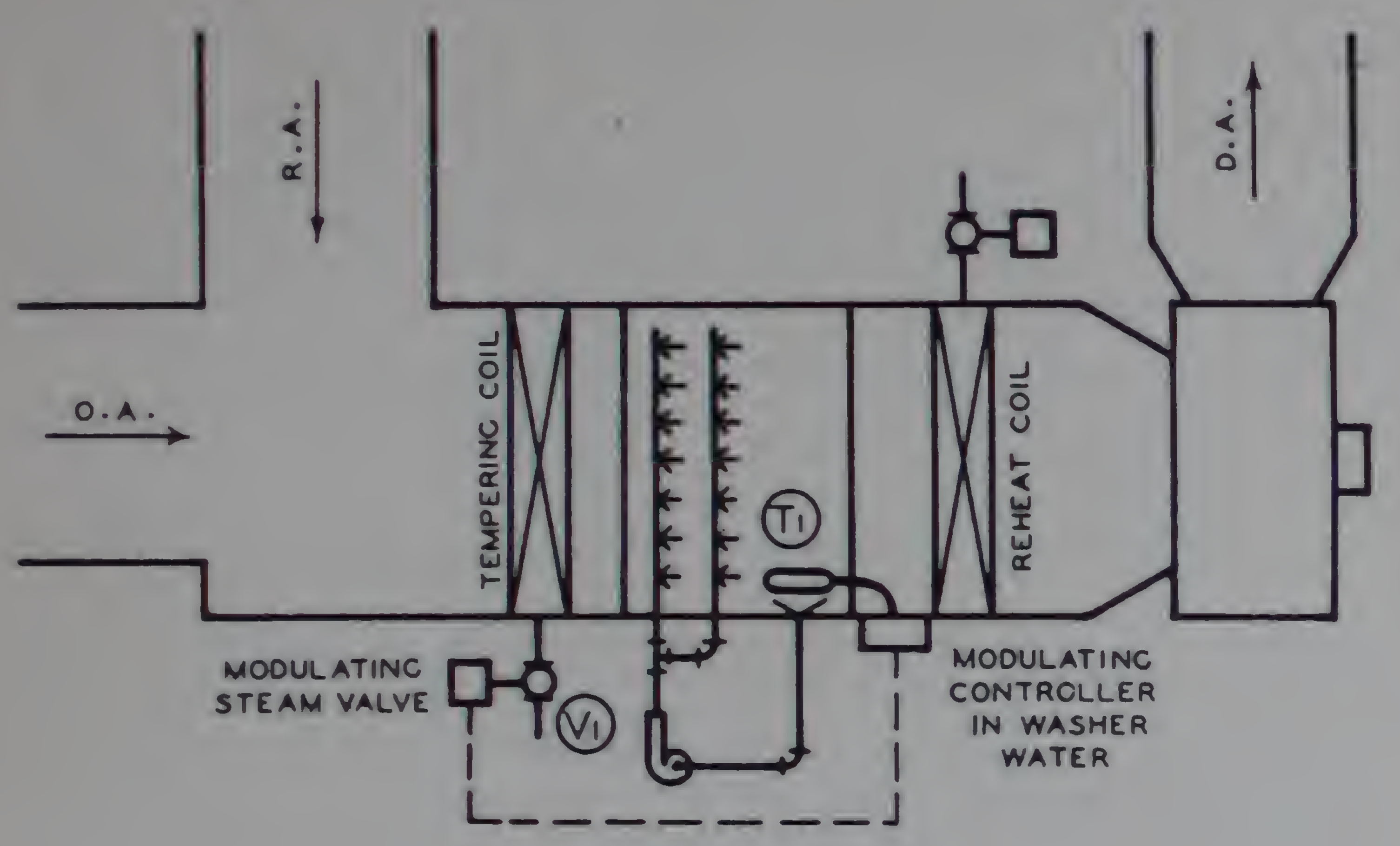


Figure 28

Fig. 28 illustrates a typical application utilizing an air washer for winter humidification, with dew point control.

The modulating controller T_1 located in the washer water near the suction line intake operates the modulating steam valve V_1 on the tempering coil.

The controller T_1 is set to maintain a washer water temperature which will provide a substantially constant dew point in the discharge air.

It is desirable to use a temperature controller to limit the washer water temperature when a humidity controller is used to control the tempering coil. The washer water temperature is held within fixed limits, thus preventing the possibility of excessive moisture delivery for short periods or freezing of the washer water when the humidity control is satisfied.

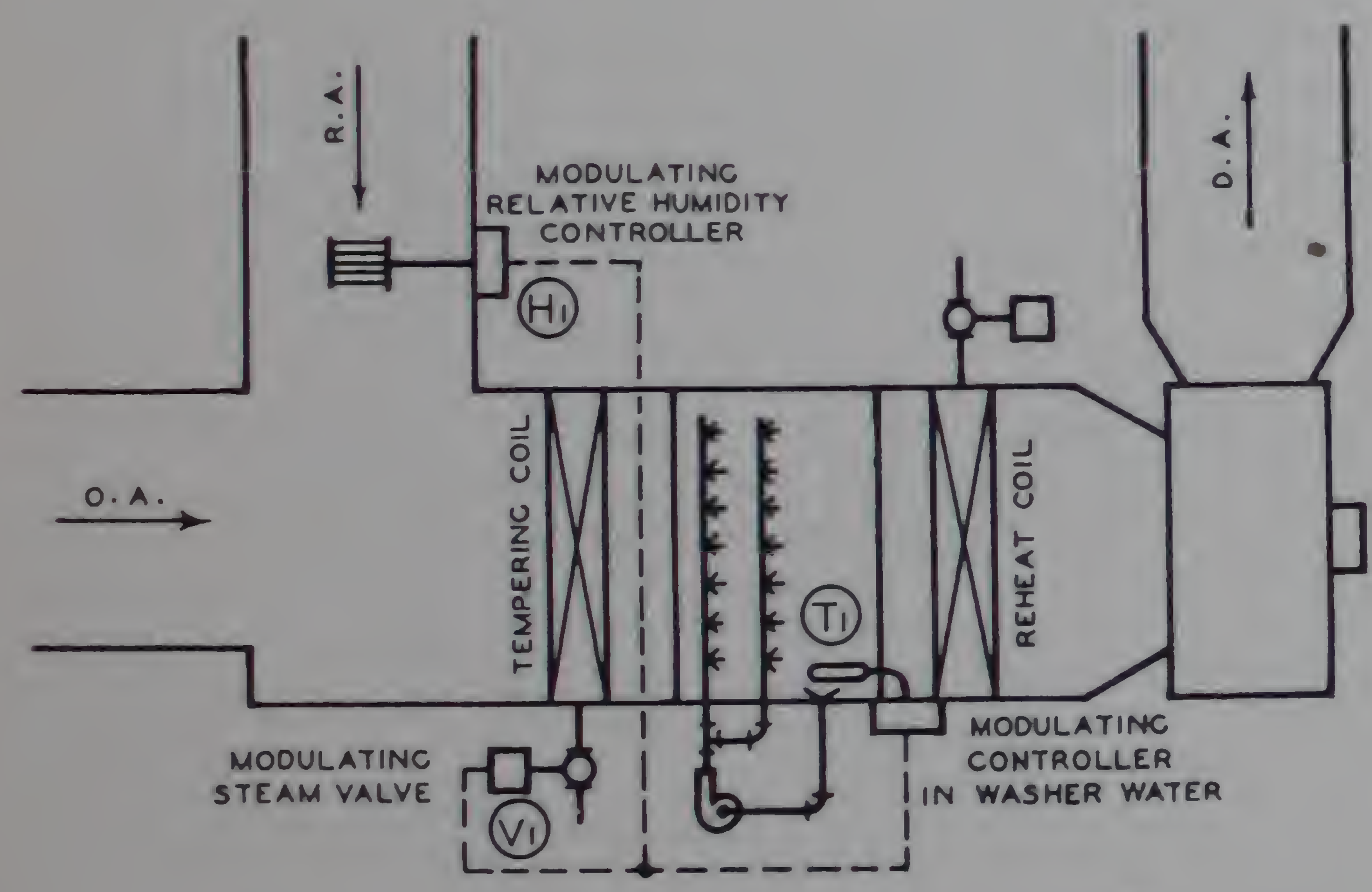


Figure 29

Fig. 29 illustrates a washer system similar to that shown in Fig. 28, excepting that a humidity controller has been added to maintain even closer limits on relative humidity conditions in the space.

As in Fig. 28 the modulating controller T_1 operates the modulating valve V_1 on the tempering coil.

The relative humidity controller is of the compensating type and is so interconnected with the water temperature controller T_1 that it may reset the control point of T_1 between any desired limits such as from 50° to 55°.

As the relative humidity of the space falls, H_1 raises the control point of T_1 to add more moisture to the air and vice versa.

Sometimes water heaters are used in place of a tempering coil to provide the necessary heat for humidification.

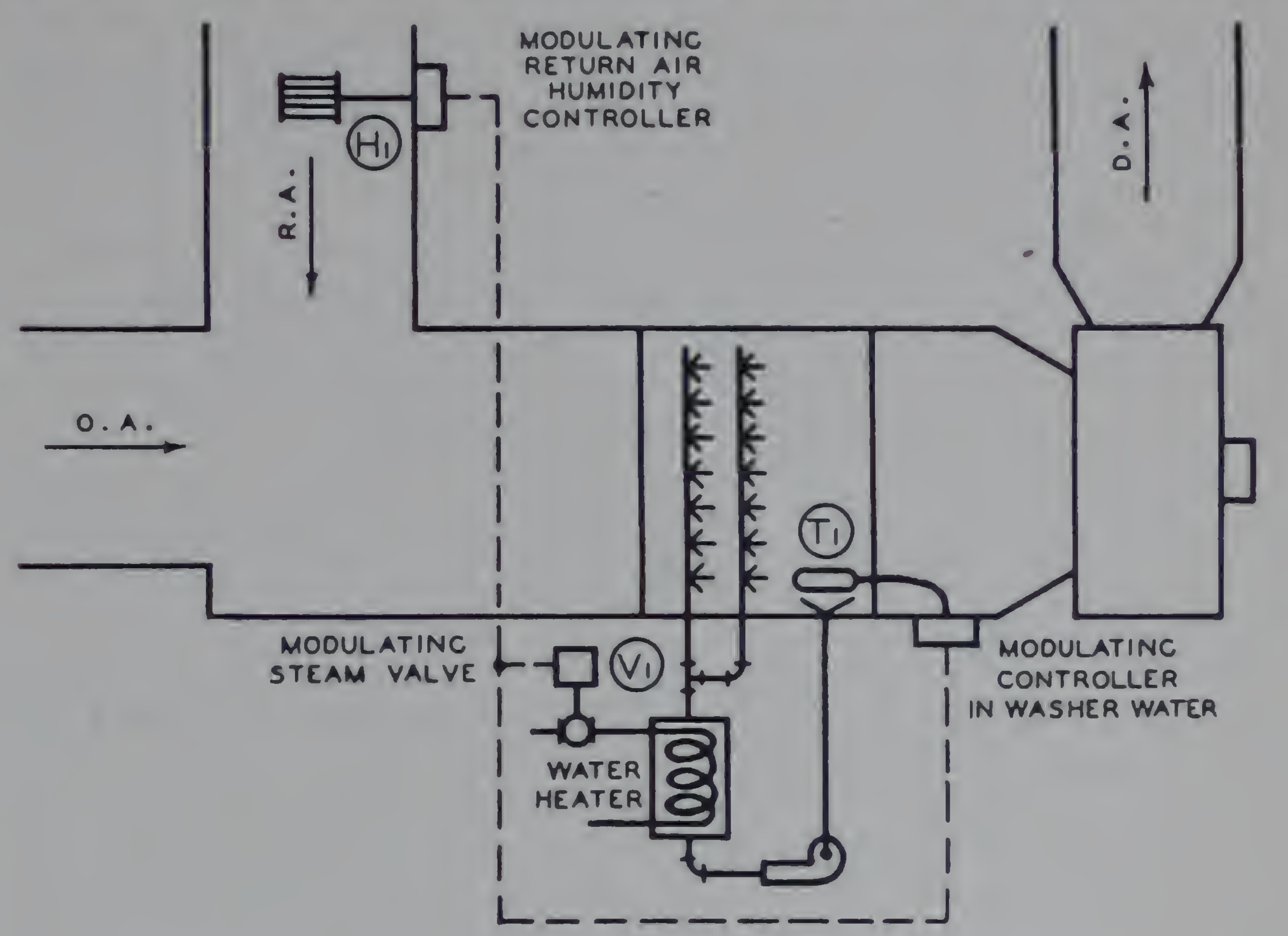


Figure 30

Fig. 30 shows a typical application using a water heater with control sequences identical to Fig. 29.

Relative Humidity Control Location

Normally a relative humidity of approximately 35% is desirable during the heating season. Under some conditions this may cause frosting of the windows. Where this is objectionable, a system of control may be provided whereby the relative humidity is varied dependent on outdoor temperatures. Thus the humidity will never be high enough to cause frosting.

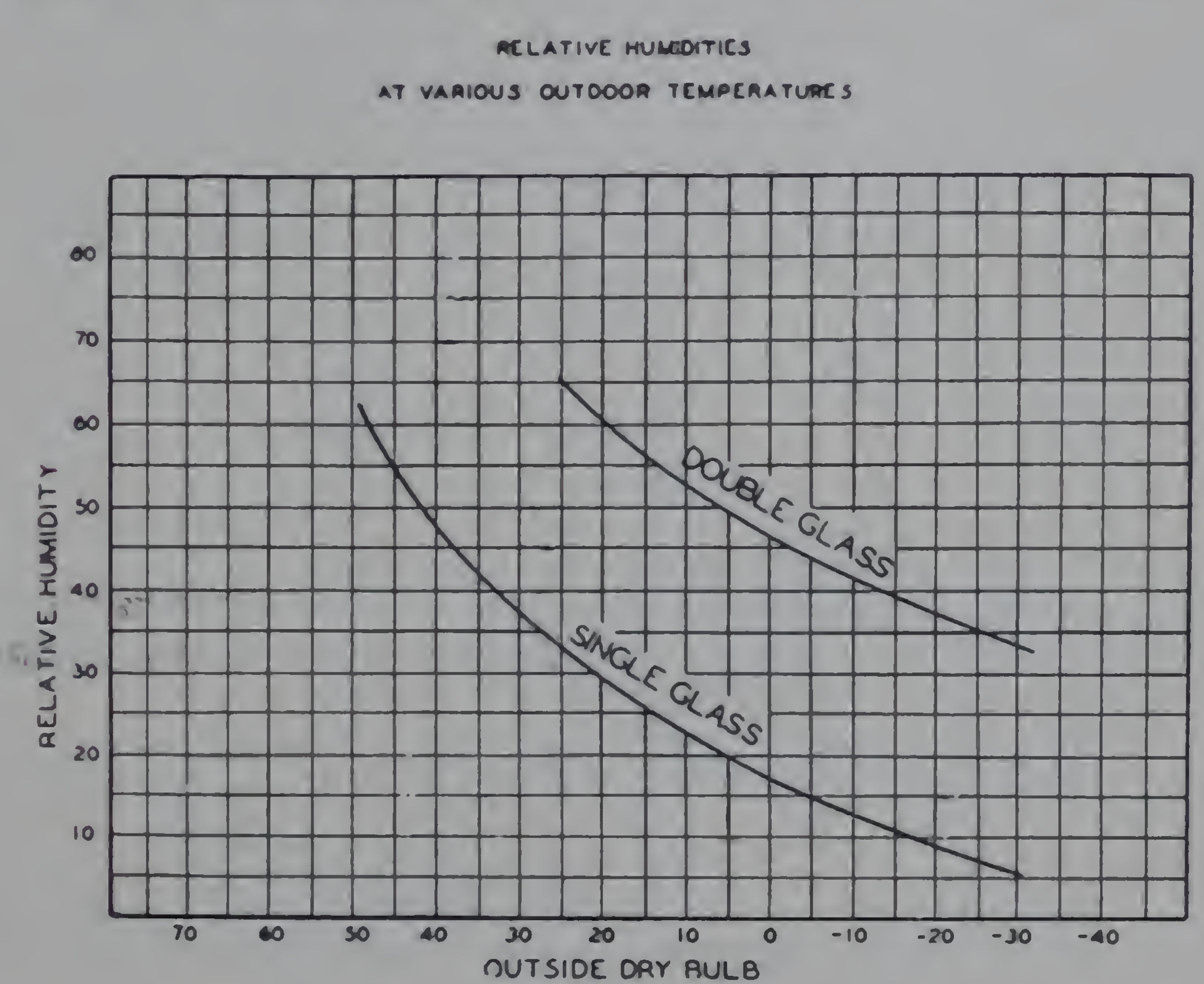


Figure 31

Fig. 31 illustrates graphically the maximum relative humidity that may be carried without frosting for both single and double paned windows. The curves are based on inside temperatures of 70° and a wind velocity of 15 miles per hour. These curves are subject to slight corrections for different types of construction, but serve to illustrate that the relative humidity maintained within a space should be definitely lowered in colder weather if frosting is to be prevented.

While these values of relative humidity may prevent window condensation, they may not prevent condensation on doors or within the walls.

CONTROL OF CENTRAL FAN HEATING SYSTEMS

The control systems illustrated in Figs. 25 through 30 have made use of either a return air or a room type humidity controller.

Where automatic compensation for changing outside temperatures and a reduction in inside humidity to prevent frosting on windows is desired, it is recommended that the room type humidity control be used.

In order to obtain such automatic reduction in relative humidities for purposes of prevention of frosting, it is recommended that the humidity control be mounted immediately below the window sill or mounted on the side of a window recess adjacent to the glass surface.

In choosing a window for such mounting, it is recommended that a window on the north side of the building be chosen or on whatever side is subject to the severest cold and wind effect.

As the surface of the glass begins to drop in temperature, the relative humidity of the air adjacent to the glass or the relative humidity of the air which drops down across the face of the glass increases. The effect of this increase is immediately sensed by the humidity controller when so mounted and it will maintain the relative humidity at a point sufficiently low to prevent condensation and frosting.

Thus, under warmer weather conditions, the desired relative humidity will be maintained in the space and the humidity level will gradually drop as the outside temperature drops, thus preventing frosting.

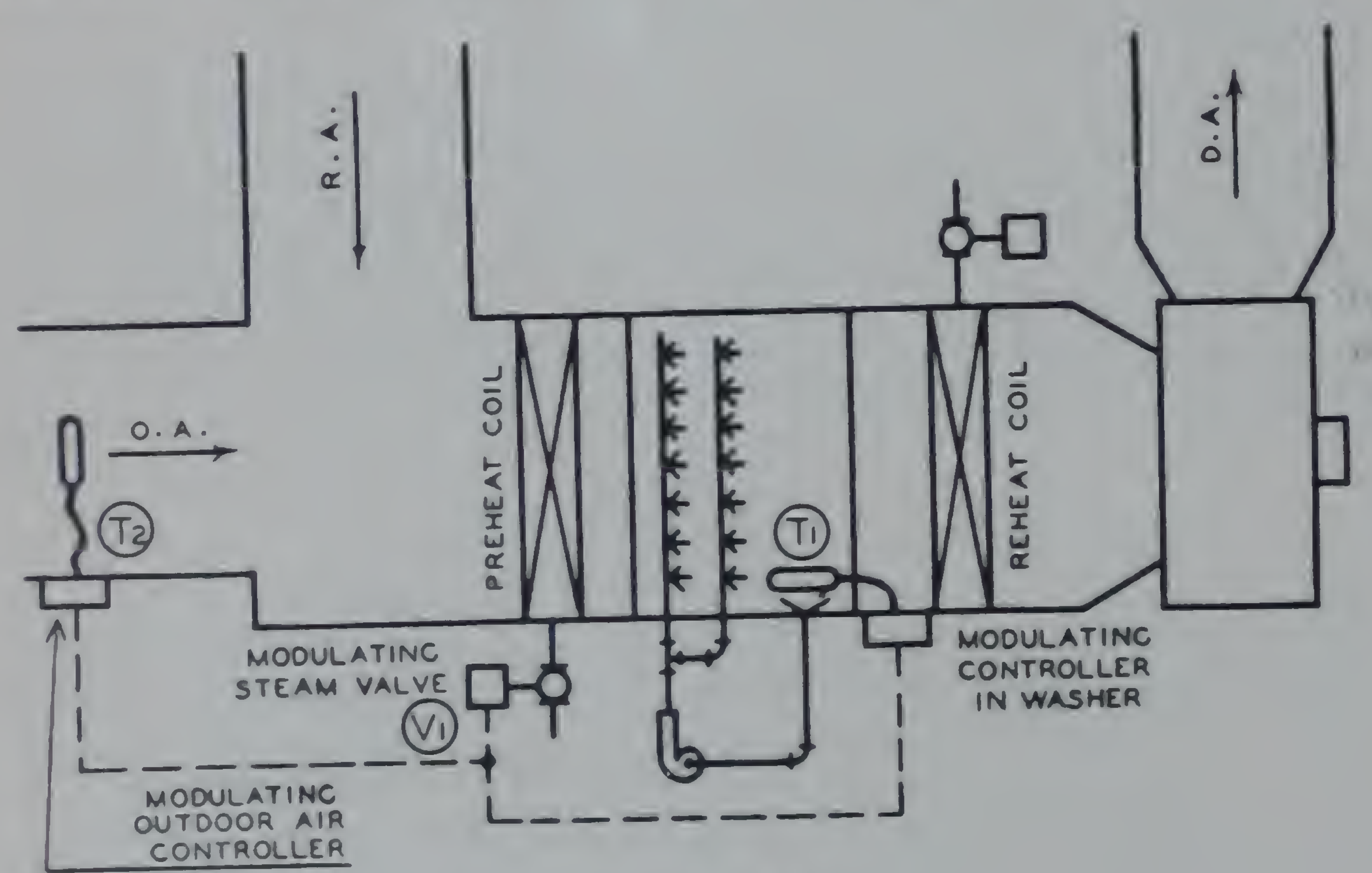


Figure 32

Fig. 32 illustrates the application of compensated relative humidity control to washer systems using either a tempering coil or water heater.

The outdoor temperature controller T_2 compensates the setting of the washer water controller T_1 to vary the temperature of the washer water with outdoor air temperature. As the outdoor air temperature rises, the control point of T_1 is raised to provide more moisture to the space, and vice versa.

The control stops the washer sprays at some low outdoor temperature as it is impossible to maintain them in operation without raising the relative humidity above the frosting point.

The system shown in Fig. 32 can be further amplified by the inclusion of a room type humidity control. Where the room type humidity control is used, the compensated dew point control is set up to provide a high limit on dew point of the discharge air. The humidity control will then have the ability to change the dew point to maintain a constant relative humidity in the space only up to the point where a decreased dew point is established by the outdoor air controller in order to prevent moisture condensation.

DISTRIBUTION AND ZONE CONTROL

The distribution of air in a conditioning system plays an extremely important part in the results obtained. If an installation is to give complete satisfaction, the various parts of the space must be supplied with air in proportion to the existing load.

The load will vary with the following factors:

1. **Occupancy.**
2. **Exposure.**
3. **Internal loads such as lights, mechanical equipment, stoves, etc.**

Thus a room or space with northern exposure will require more heat than a similar space facing south.

Likewise, a general office space where occupants are physically inactive will require more heat than a factory space where heavy physical labor is accomplished.

These conditions of varying load, providing the fluctuations are not too wide, may usually be satisfactorily handled by proper design of the ductwork and outlet grilles.

When conditions vary widely, it is usually necessary to use zone control in some form so that the amount of heating or cooling for each space may vary with individual requirements.

Zoning for Central Fan Systems

There are three methods for controlling the heat delivery from a central fan system.

1. **Constant air volume delivered at varying temperature.**
2. **Varying air volume delivered at a fixed discharge temperature.**
3. **A combination varying both volume and temperature.**

CONSTANT AIR VOLUME

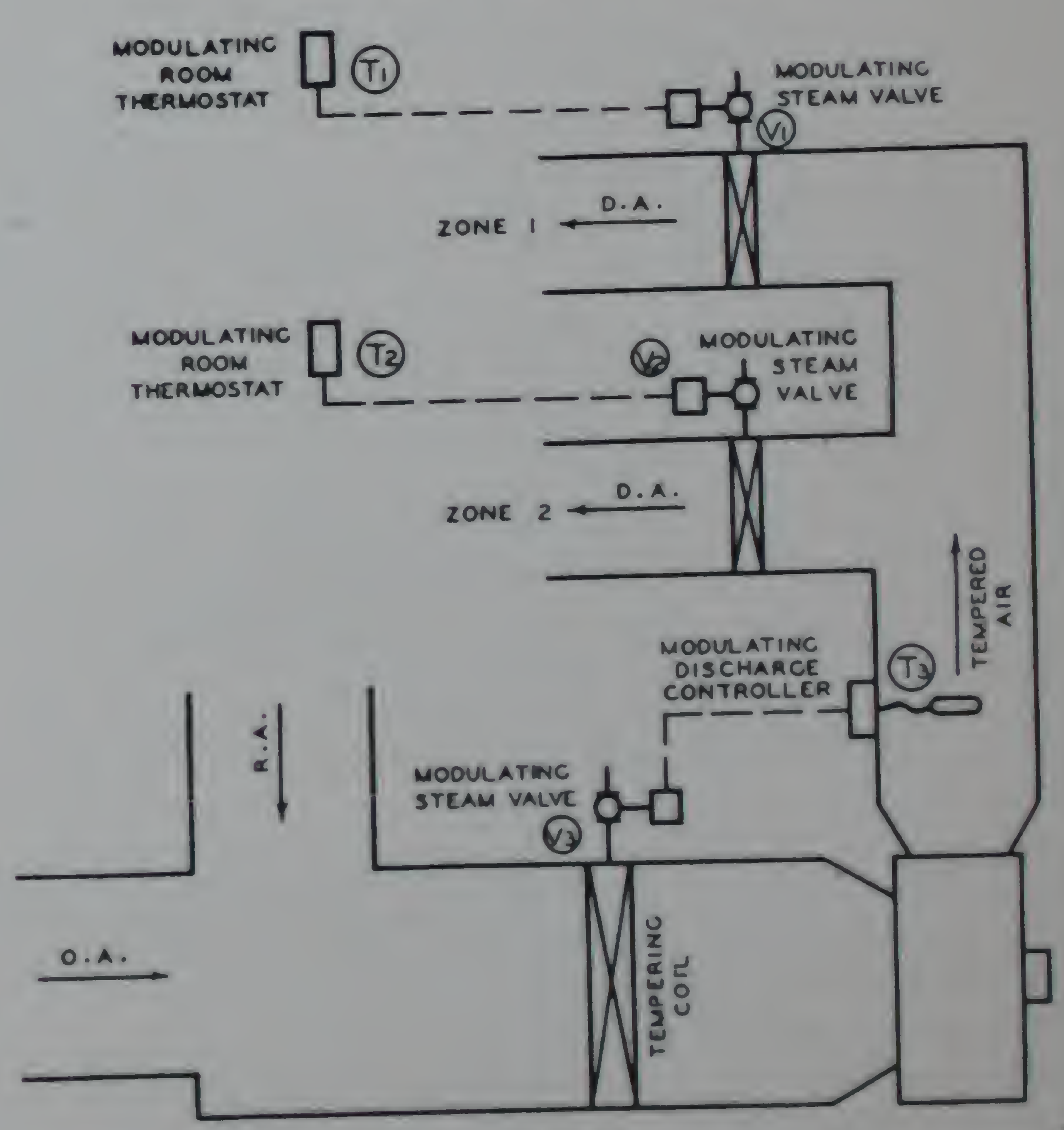


Figure 33

A constant volume system has the following advantages:

1. **A means of cooling, if needed, during the winter season.**
2. **A constant volume of air with full ventilation.**
3. **A constant grille velocity providing even distribution.**

CONTROL OF CENTRAL FAN HEATING SYSTEMS

Fig. 33 illustrates a two-zone system arranged for constant air volume and varying discharge temperature.

A modulating controller in the fan discharge operates a modulating steam valve on the tempering coil to maintain a 65° discharge air temperature.

Room thermostats in each of the zones operate modulating steam valves on booster heater coils in accordance with heat demands in the zones.

When the zone temperature rises above normal, the booster coil valve is closed, and 65° air is delivered for cooling purposes.

Varying Volume Systems

Fig. 34 illustrates another type of constant volume varying temperature control.

This system makes use of one tempering coil and one reheat coil for all zones with the ductwork so arranged as to take the necessary proportions of tempered and heated air for each zone individually.

The modulating discharge controller T_1 in the fan outlet maintains a discharge temperature of, say, 65° by operation of the modulating valve V_1 on the tempering coil.

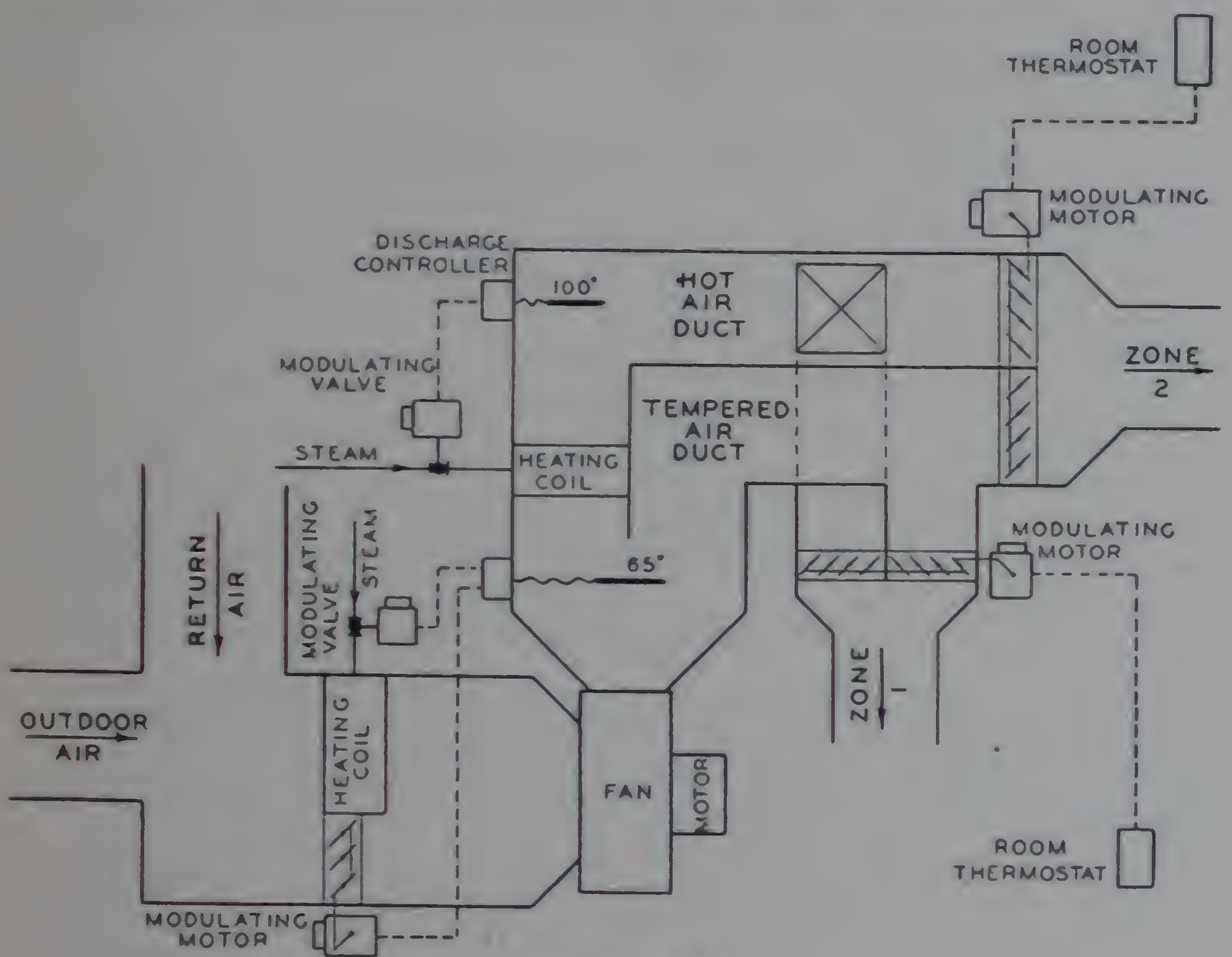


Figure 34

The modulating controller T_2 located beyond the booster coil in the hot air duct operates the steam valve V_2 to maintain a hot air duct temperature of, say, 100°.

Dampers are placed to control the proportions of hot and tempered air supplied to each zone duct as shown for Zone No. 2. A modulating room thermostat operates a modulating motor to vary the amount of hot and tempered air supplied to each zone.

Should the space tend to overheat, only tempered air will be supplied to the zone to provide cooling.

While this system has been shown applied to a fan system utilizing heating coils, a similar arrangement is common when warm air furnaces are used. Dampers and ductwork are so arranged that the warm air from the bonnet may be mixed in varying proportions with tempered air by-passed around the furnace so as to provide identical results as shown in Fig. 34.

Though systems providing a varying volume of constant temperature air similar to those shown in Fig. 35 are sometimes used, it is difficult to control them unless very good air distribution is obtained.

A controller in the fan discharge operates a modulating steam valve and by-pass damper to maintain constant discharge temperatures. The discharge controller must be set high enough to provide for the maximum heat loss.

In each of the zones a room thermostat operates a modulating damper motor to vary the volume of air delivered in accordance with heat loss requirements.

A static pressure regulator operates a damper at the fan inlet to maintain a constant discharge duct pressure so that the same volume of air will always be discharged for any given position of a zone volume damper, and so that noise resulting from high pressure will not be encountered.

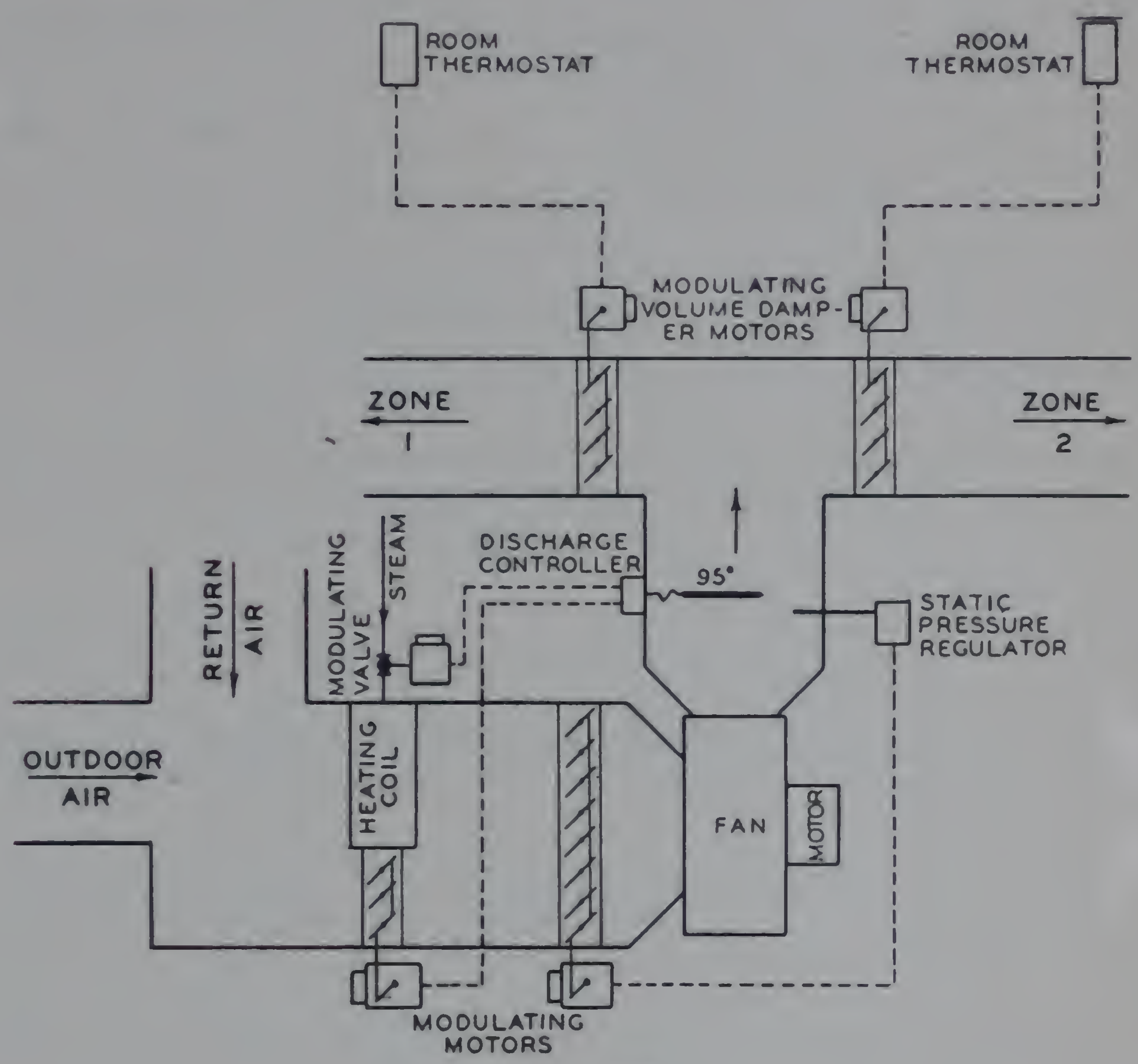


Figure 35

There are certain inherent disadvantages in a system of this sort.

1. Since the discharge air temperature is fixed, it is not possible to provide cooling if it should be required.
2. In mild weather, as the heating load becomes less, volume of air delivered is progressively reduced to balance heat losses. This has the effect of impairing the ventilation.

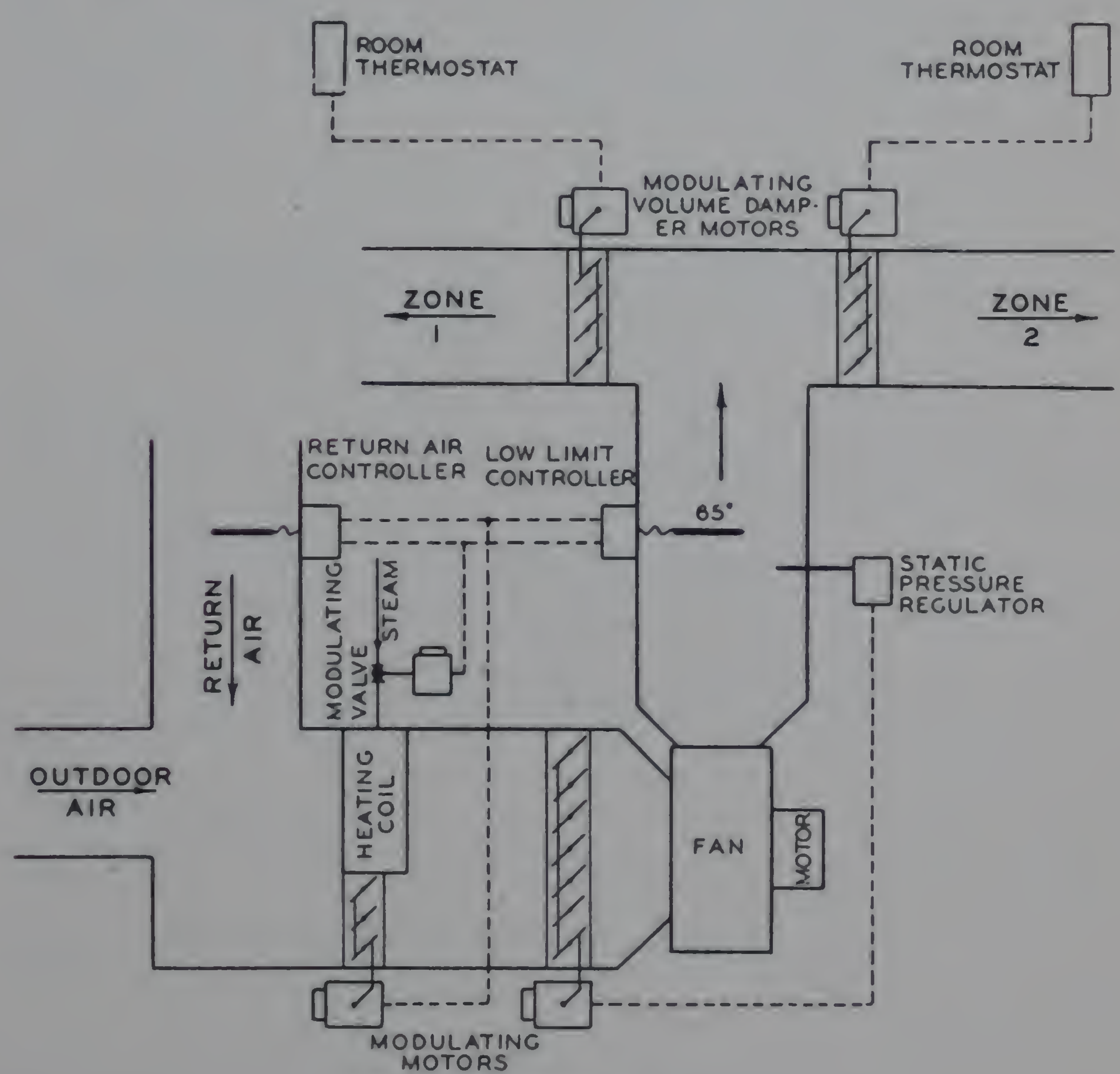


Figure 36

CONTROL OF CENTRAL FAN HEATING SYSTEMS

If a varying volume system is used its operation may sometimes be improved to some extent by the addition of a return air controller for varying temperature as shown in Fig. 36. It is not possible to equal the results obtained from a constant volume system in every case, but they may be improved by proper control and adequate distribution.

1. The room thermostats control their respective volume dampers as in Fig. 35.
2. The static pressure regulator operates as in Fig. 35.
3. The return air controller is so adjusted that it will attempt to maintain a return air temperature equal to the average return air temperature when all zones are at their desired condition. It does this by throttling the modulating steam valve and by-pass damper to reduce the discharge air temperature.
4. The modulating controllers in the discharge fan act as a low limit to prevent the discharge of air below, say, 65°, should the return air controller become completely satisfied.

Assume that the system is started with both zones below temperature.

1. The volume dampers will be wide open and the maximum temperature of discharge air will be delivered.
2. As the zones rise in temperature, their respective volume dampers will throttle at the command of the room thermostat.

Due to the rise in zone temperature, the return air will also rise causing the steam valve to throttle to reduce the maximum discharge air temperature.

Thus the heat delivery to the space is reduced not only by reducing the volume of air supplied, but also by reducing the temperature of air supplied. Consequently it will not be necessary to reduce the air volume quite as far as would be the case for a system as shown in Fig. 35.

Note: Some volume control systems regulate each outlet individually by means of a separate control damper. A new type of volume control damper, available for this type of installation, provides constant air velocity through the outlet grill from 25% to 100% capacity. These dampers are known as Vol-U-Trol dampers and are described on page 44 of Section One. Because of their constant velocity characteristics the air distribution will not suffer as Vol-U-Trol dampers throttle the air supply.

A zone system is sometimes designed so that each side of the building is zoned separately. In this way, for instance, the north, south, east and west zones are controlled separately so as to take advantage of the differing exposure factors.

If, in this system, the separate zones are made up of a series of offices along each outside wall, it will be noted that the corner offices are subject to the exposure factors common to two different zones. The northwest corner office, if it is included in the north zone, may be overheated when the sun effect is greatest during the afternoon, or the southeast office, if it is included in the southern zone, may be underheated after the middle of the day, and so on.

One way in which this condition may be overcome is to supply air to a corner office from each of the two zones adjacent to that office in proportions equal to the exposures of that office. A corner office that has equal exposures on the south and west sides of the building would have equal quantities of air delivered to it from the south and west zones. In this way a fairly equitable balance is reached allowing the room to be maintained at better average conditions.

In a properly designed air-conditioning system each automatic control unit performs a definite function. If the principles of control application are thoroughly understood, each section of a control system may be easily evaluated in terms of:

1. **Increased comfort to the user of the system.**
2. **Self-liquidating economies.**
3. **Realization of the full value of the system.**

Without a carefully designed control system many of these values will not be completely realized and the return on the owners' investment correspondingly reduced.

Research and experience have definitely indicated those control sequences which will produce the most complete and satisfactory results from any given arrangement of mechanical equipment.

In the following section various control sequences are analyzed with direct reference to their application in conjunction with equipment used in central fan cooling systems. While the discussion refers directly to central fan air-conditioning systems, the principles developed are equally applicable to unit type air-conditioners.

Control of Central Fan Cooling Systems

The summer air-conditioning system must control the temperature and moisture content of the air as well as provide ventilation, circulation, and cleaning.

The first types of system to be considered are those wherein moisture removal, or dehumidification, is accomplished incidental to the cooling of air.

In most air-conditioning systems air is cooled to a temperature below the dew point of air in the space being conditioned and under these circumstances the air-conditioning plant is said to have a capacity for absorbing latent heat or moisture. The extent of this capacity for dehumidification will depend upon the type of refrigerant utilized and the cooling surface over which the air passes.

From the standpoint of heat exchange surface used, central fan cooling systems fall generally into these classifications:

1. **Systems providing cooling through the use of finned coils, cold water, or brine being used as a refrigerant.**
2. **Direct expansion systems. Cooling is provided by the expanding of liquid refrigerant into a finned coil, cooling being accomplished because of evaporation of the refrigerant in the coil.**
3. **Washer systems. In this type of system there usually is no cooling surface per se, but the air is cooled in passing through a chamber in which cold water is sprayed in a finely atomized condition. In this type of system the air is brought down to a nearly saturated condition at a dew point determined by the water temperature used.**

A further classification of cooling systems may be made with reference to the arrangement of the plenum chamber. Most of the systems illustrated in this section are shown with the fan drawing air through a conditioning chamber and discharging it to the duct system. Actually this arrangement is frequently reversed so that the fan will force the mixture of return and outside air through the cooling surface and thence to the duct system.

The plenum chamber or conditioning unit generally takes one of the following forms:

CONTROL OF CENTRAL FAN COOLING SYSTEMS

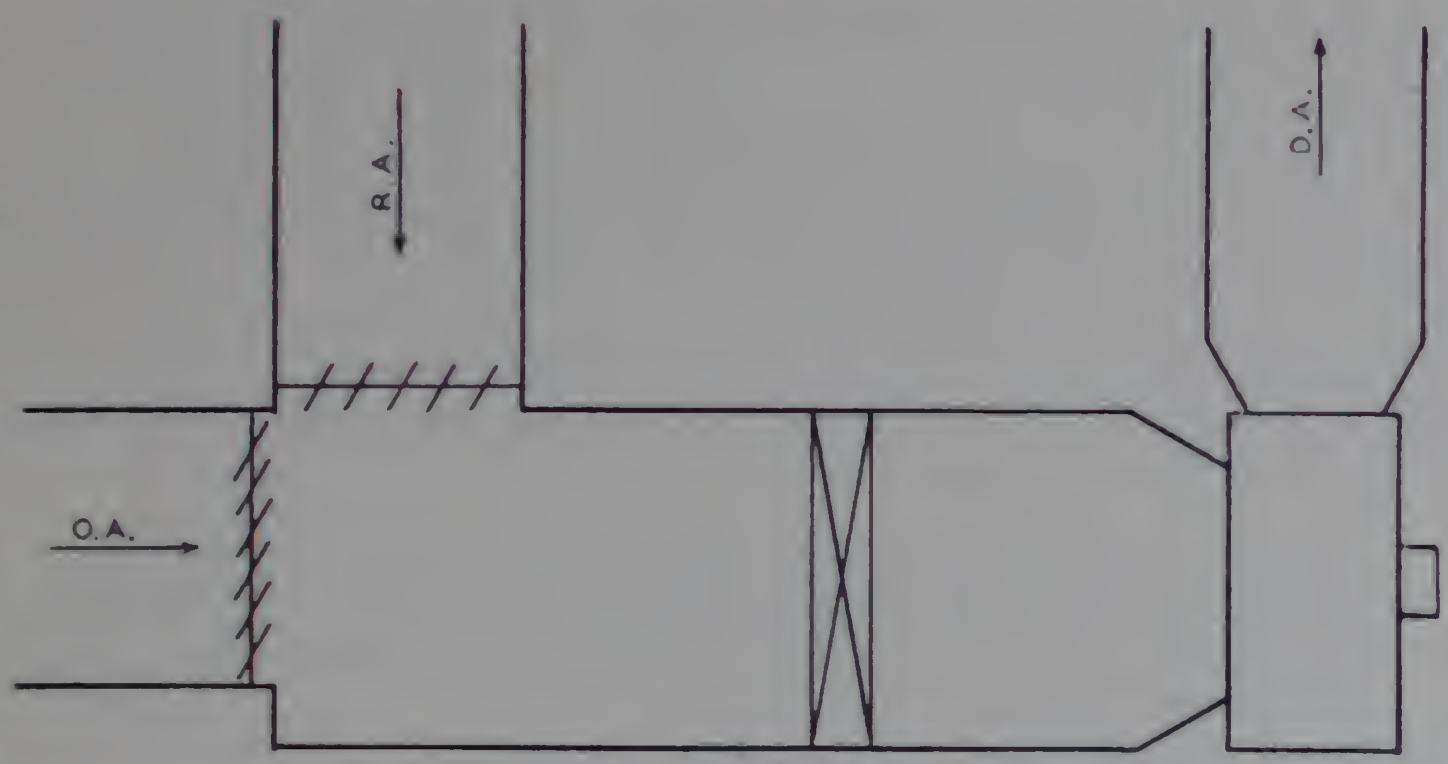


Figure 1

Single Pass System.

In such a system all of the conditioned air will pass through the cooling coil or washer. (Fig. 1.)

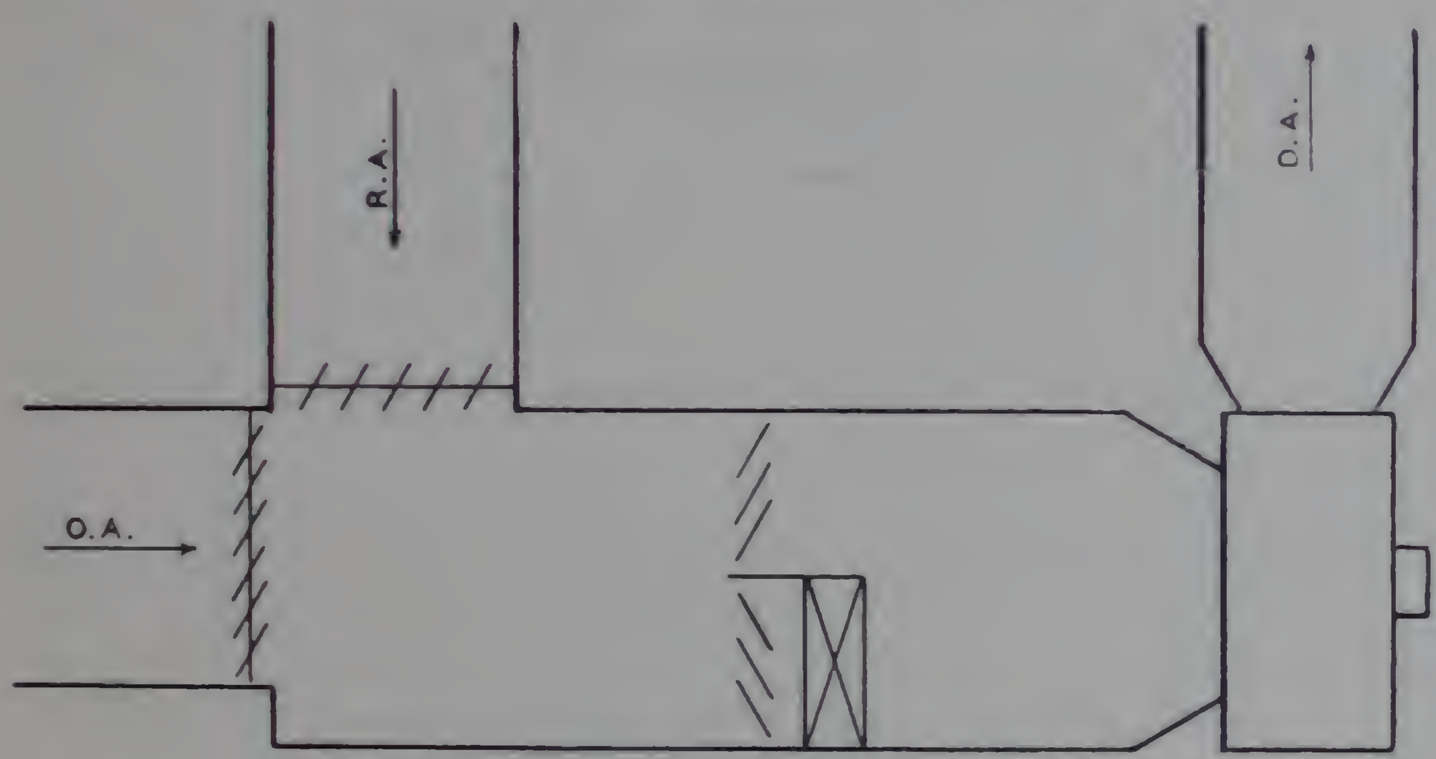


Figure 2

Face and By-Pass System.

On systems of this type dampers are usually placed across the surface of the cooling coil or washer chamber, and a by-pass duct with damper permits part of the air to pass completely around the cooling coil or washer. These dampers are generally operated together so that as one closes the other opens. On this type of system all of the air does not pass through the coil since some of it is by-passed and the air that is by-passed may be a mixture of outside and return air. (See Fig. 2.)

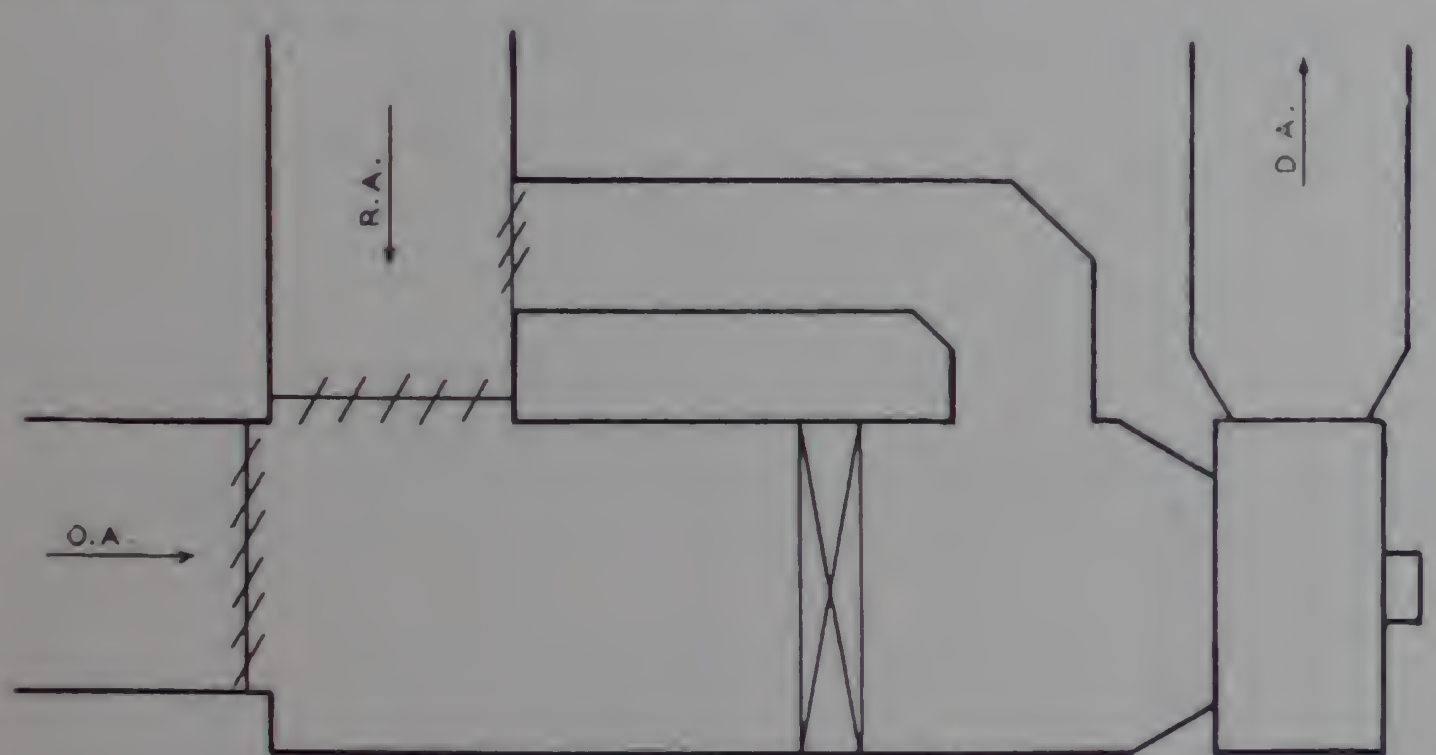


Figure 3

Return Air By-Pass.

This type of system is similar to the one just described. Instead of the by-pass handling a mixture of outside and return air, the by-passed air comes directly from the return air duct and dampers are installed at that point. The air that is by-passed and mixed with conditioned air is return air from the rooms being served. (See Fig. 3.)

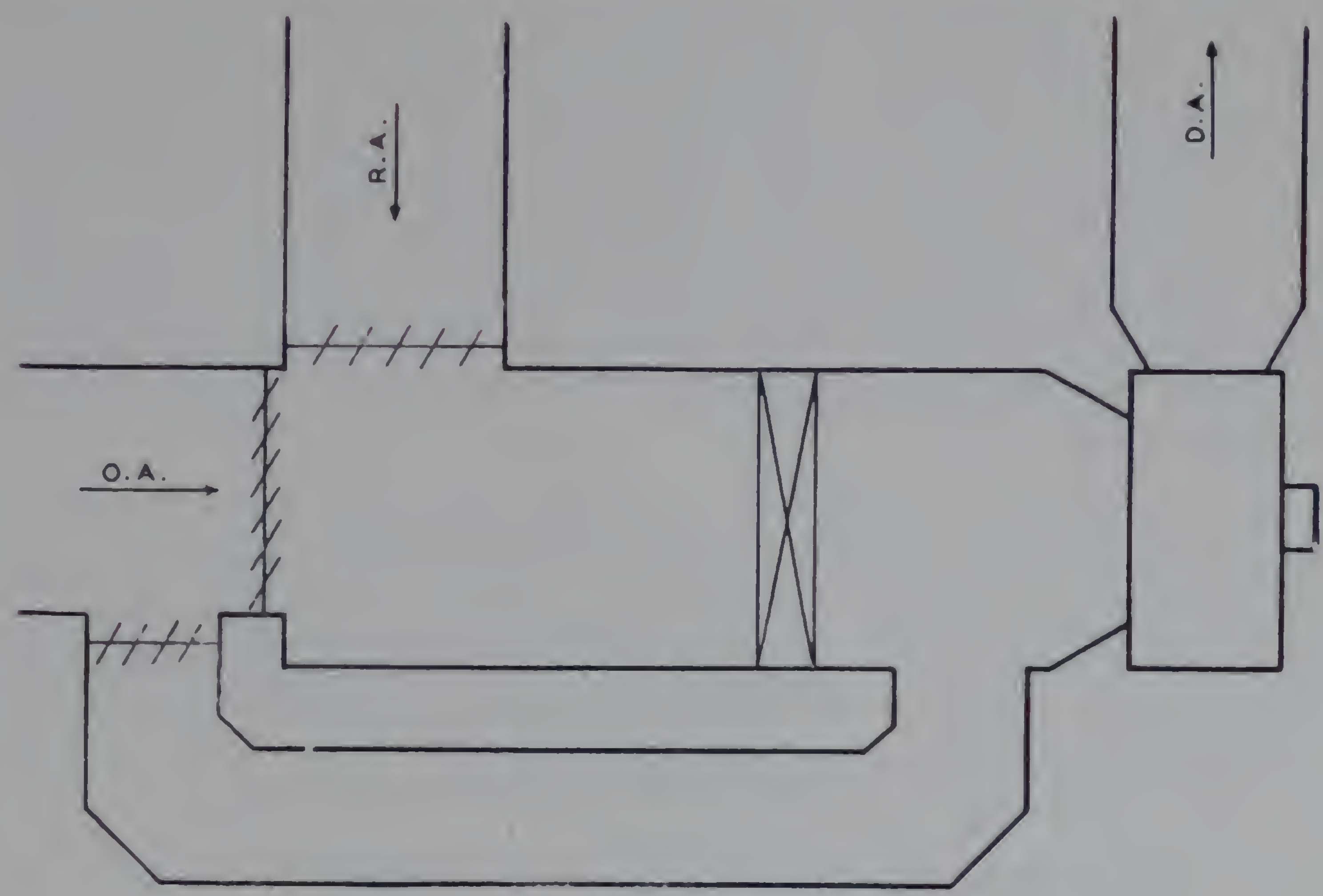


Figure 4

Outside Air By-Pass.

This type of arrangement is occasionally used and again is similar to those just described with the exception that the air by-passed comes from the outside air duct. (See Fig. 4.)

The design of both the cooling surface and the plenum or conditioner chamber will depend largely upon conditions of load peculiar to individual installations. Controls may be applied to any combination of cooling surface and plenum design.

CONTROL OF SYSTEMS USING COLD WATER COOLING COILS

Cold water when used as the refrigerant in an air-conditioning system may be obtained from any of the following sources:

Deep Wells

In some localities low temperature water is available from wells and this may be used as a low cost refrigerant. Pumps are used to provide the required circulation. Generally some type of storage is provided so that the water can be circulated through the coils intermittently as required.

Water Coolers

Where low temperature well water is not available, mechanical refrigeration is used to reduce the temperature of water circulated through indirect coolers. Generally this type of system is set up as a closed circuit and water leaving the conditioner coil is returned to the indirect cooler for further refrigeration. This prevents the wasting of partially cooled water and increases the economies of operation.

In this type of system automatic control is generally applied to:

1. **Pump which provides circulation of the water.**
2. **A motorized valve which controls the flow of water to the coil.**

In either case the mechanical compressor used in the refrigerating cycle is controlled from a thermostat set to maintain a constant temperature of the water leaving the cooler.

Indirect Ice Systems

Where a system of this type is used, water returning from the coils is sprayed over the ice which is located in bunkers. The chilled water is then circulated through the coils by means of a pump.

The thermodynamics of air cooling and the factors which affect the cooling of air and removal of moisture from it have already been discussed on page 8. It has

CONTROL OF CENTRAL FAN COOLING SYSTEMS

been determined that the temperature of the coil surface has a definite effect upon both of these functions and it is necessary that the extent of this effect be given careful consideration before designing the automatic control system. Failure to analyze this effect carefully may result in the selection of controls which will be unable to provide the desired results. **Controls cannot maintain conditions which are beyond the limitations of the cooling equipment as determined by coil surface temperature, volume of air handled, etc.**

As an example refer to the drawing on page 14 which illustrates the psychrometric relationship between air delivered from a conditioner unit and air within the conditioned space. It may be noted that a dry bulb temperature of 80° may be attained within the conditioned space by a coil the surface temperature of which is 53° as shown at "B", with air discharged at 58° as at "C", by:

1. **Discharging a given quantity of air at condition "C" of 58° dry bulb, or**
2. **Discharging twice as much air at 69° dry bulb.**

Under either circumstance the design conditions can be met. However, if the 69° air is at a condition falling above the line "AC" rather than on it, the amount of latent cooling will not be sufficient and the relative humidity will rise.

It can therefore be understood that the higher the coil temperature becomes, the more difficult it is to maintain the desired relative humidity even though it may be entirely possible to maintain the proper dry bulb temperature level.

In this example a relative humidity of 40% and 80° dry bulb could not be obtained regardless of controller demands because of the actual limit of conditioning capacity as determined by the coil surface temperature.

It is therefore obvious that the capacity of a system for removing latent heat in relation to sensible heat is something inherent in the system and determined by the coil temperature available. **It is impossible for the control system to alter an inherent characteristic of this type. When systems are carefully analyzed to determine their inherent limitations, it is possible to intelligently select a system of control which will insure the best possible results from the equipment in question.**

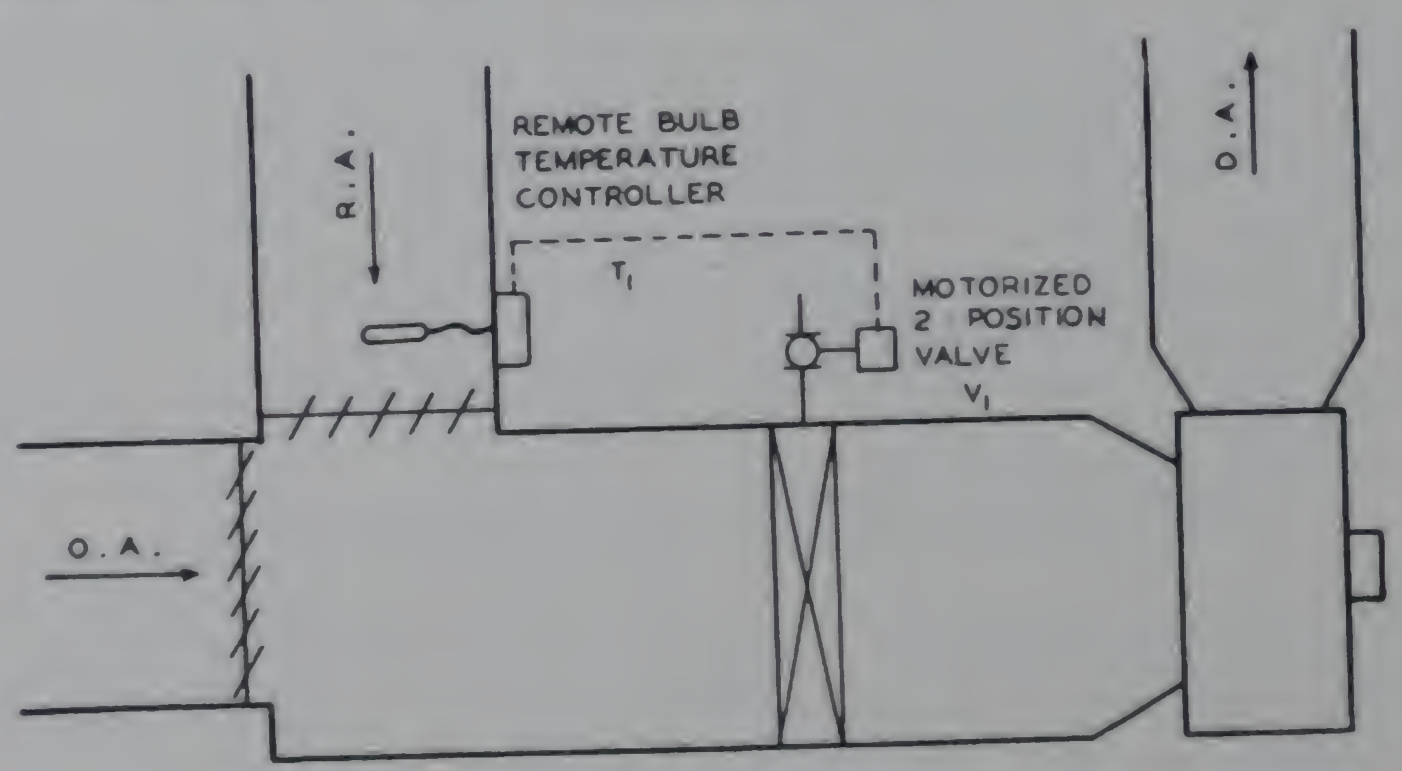


Figure 5

Fig. 5 illustrates a very common control system for cold water cooling coil installations. A return air thermostat controls the position of the motorized valve admitting cold water to the coil. (A room thermostat may be used in place of a return air controller.)

A system of this type is frequently installed in such a manner that the valve will operate with a modulating or throttling effect. During periods of light sensible heat load the valve will be throttled to prevent too much cooling. Actually, under the light sensible load conditions it is probable that percentagewise the latent heat will be very high. In other words, the S/L ratio becomes small. This will generally result in a high relative humidity since coil temperatures will rise as the volume of water delivered to the coil is reduced.

1. **Where a control system similar to that illustrated in Fig. 6 is used, it is preferable to employ two-position valve operation. With this arrangement the valve will be either open or closed and maximum dehumidification will be enjoyed whenever the coil is operative.**

It is frequently possible to control the operation of a pump directly without the use of a motorized valve. This is particularly true on systems of the indirect type where a supply of cold water is available at all times.

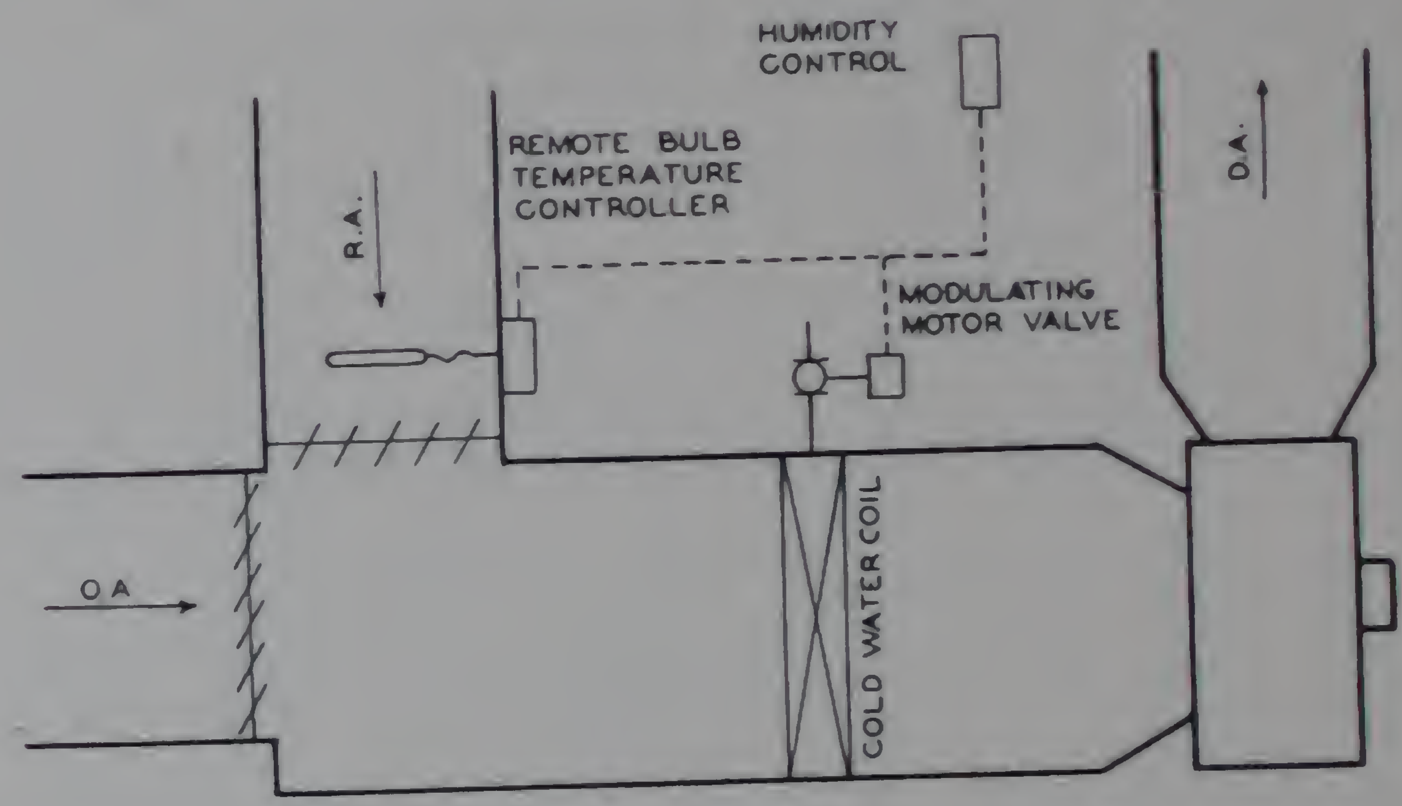


Figure 6

Fig. 6 illustrates a system of control for cold water cooling which overcomes some of the disadvantages discussed in the previous example. In this system the thermostat modulates the position of the valve in the cold water line thereby causing a variation in coil temperature to give uniform delivery temperatures.

However, in the event that the relative humidity becomes too high, the humidity control will cause the thermostat to operate the valve in a two-position manner.

1. **Therefore, when the latent load is high, the coil is operated at its lowest possible surface temperature with the result that maximum dehumidification is obtained.**

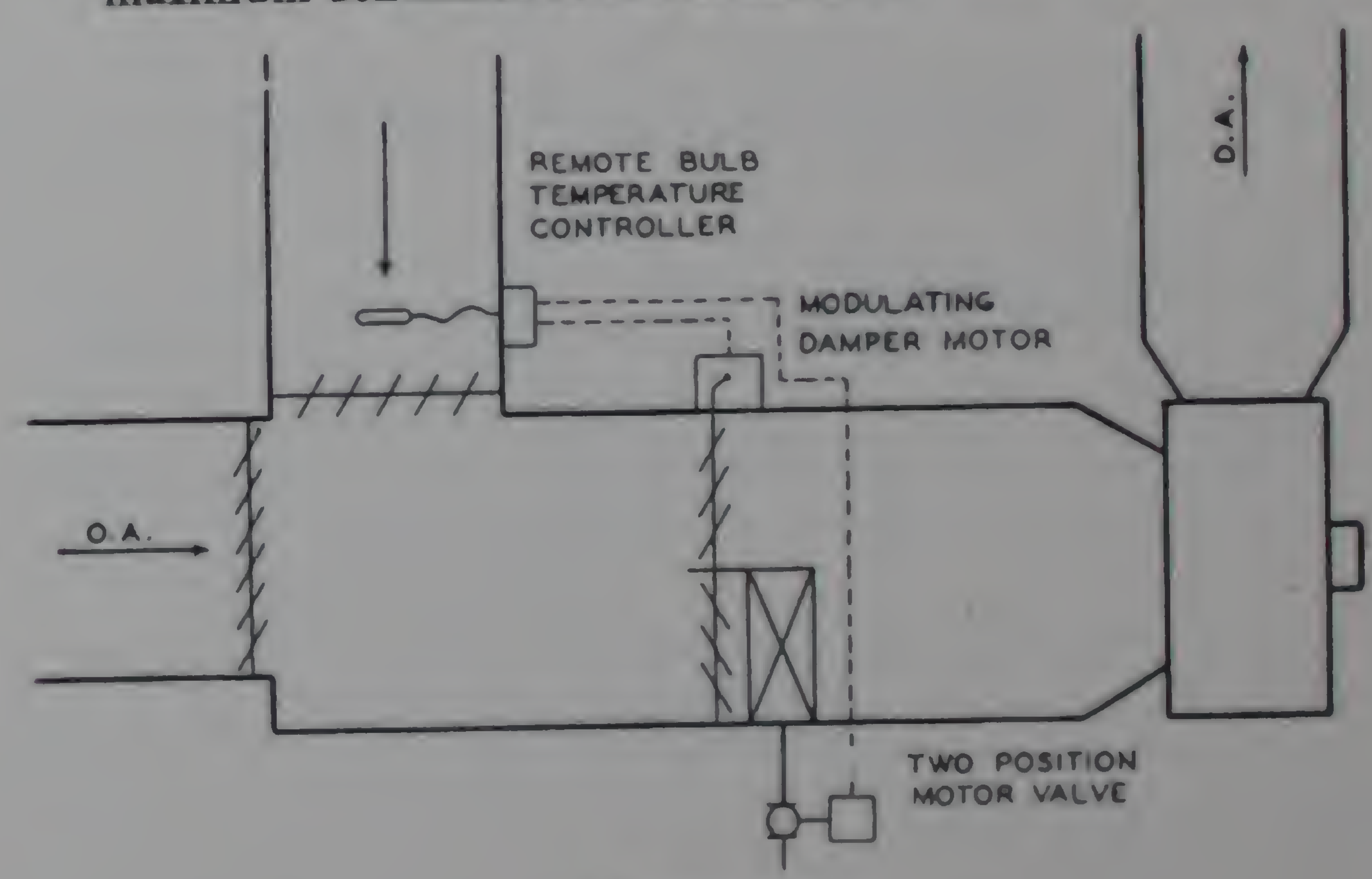


Figure 7

Fig. 7 illustrates a face and by-pass system using cold water cooling coils. When the conditioning equipment is arranged in this manner, it is possible to regulate the

CONTROL OF CENTRAL FAN COOLING SYSTEMS

temperature of the delivered air without sacrificing the dehumidifying effect of low coil temperatures. The coil is maintained at its minimum temperature level at all times and a throttling effect is gained by varying the proportions of air passing through and around it.

1. **Under light sensible load conditions slightly lower coil temperatures may result with this type of system because there will be less load on the coil due to the smaller volume of air passing through it and therefore a lesser temperature rise in the water will take place.**

The sequence of operation provides that a thermostat in the return air shall modulate a control motor which determines the relative positions of the face and by-pass dampers. These dampers work oppositely, the face damper closing as the by-pass damper opens. It is also possible to make a further provision in this system by which a valve controlling the supply of water to the coil can be closed when the face damper reaches its fully closed position, thus conserving water supply.

While a face and by-pass damper arrangement has been shown here, it is also possible to use either a return air by-pass or an outside air by-pass to obtain this same result and the control sequence used would be similar to the one shown here.

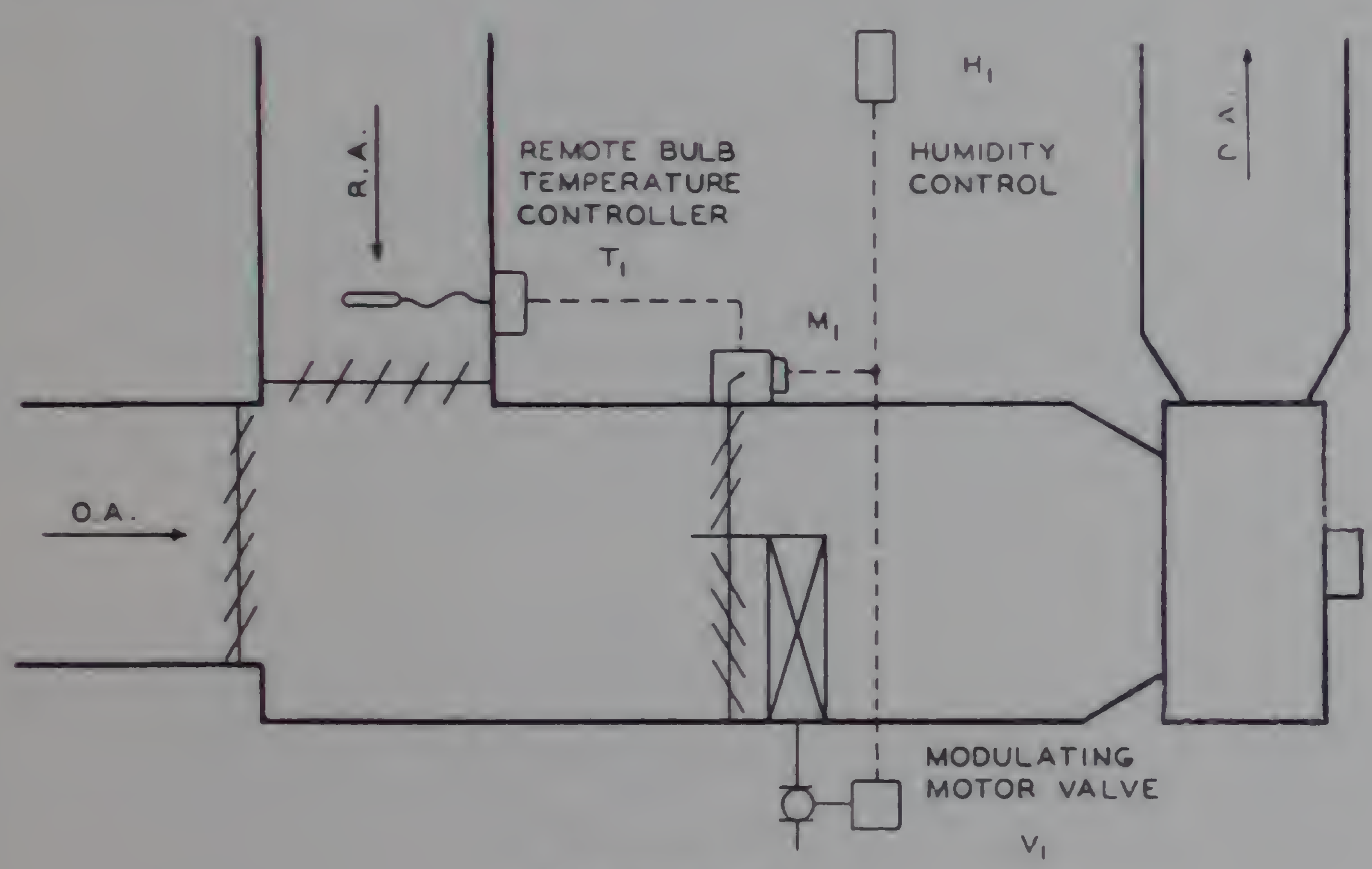


Figure 8

The system shown in Fig. 7 may be arranged to provide further economies by varying the coil temperature and permitting it to rise when no dehumidification is required. Fig. 8 illustrates a system wherein the thermostat positions the face and by-pass dampers and throttles the water valve. A relative humidity control causes the motorized valve on the coil to assume a wide open position when the humidity is high.

1. **A system of this type may be used with beneficial effect where water rates are high and where the installation of the additional controls involved is warranted on the basis of economies effected.**

Control of Water Through Cooling Coil

On large installations, particularly where water rates are high and where the water from the coils is being wasted rather than recirculated through a water cooler, it is obvious that the temperature rise through the coils is going to vary considerably depending upon the load on the coils. Particularly, during an original pick-up period or when rapid changes of load occur, the thermostat will have the valve in a wide open position and the water may be passing through the coils with very low temperature rise. This means that a considerable quantity of water is being wasted where a higher temperature rise could be allowed.

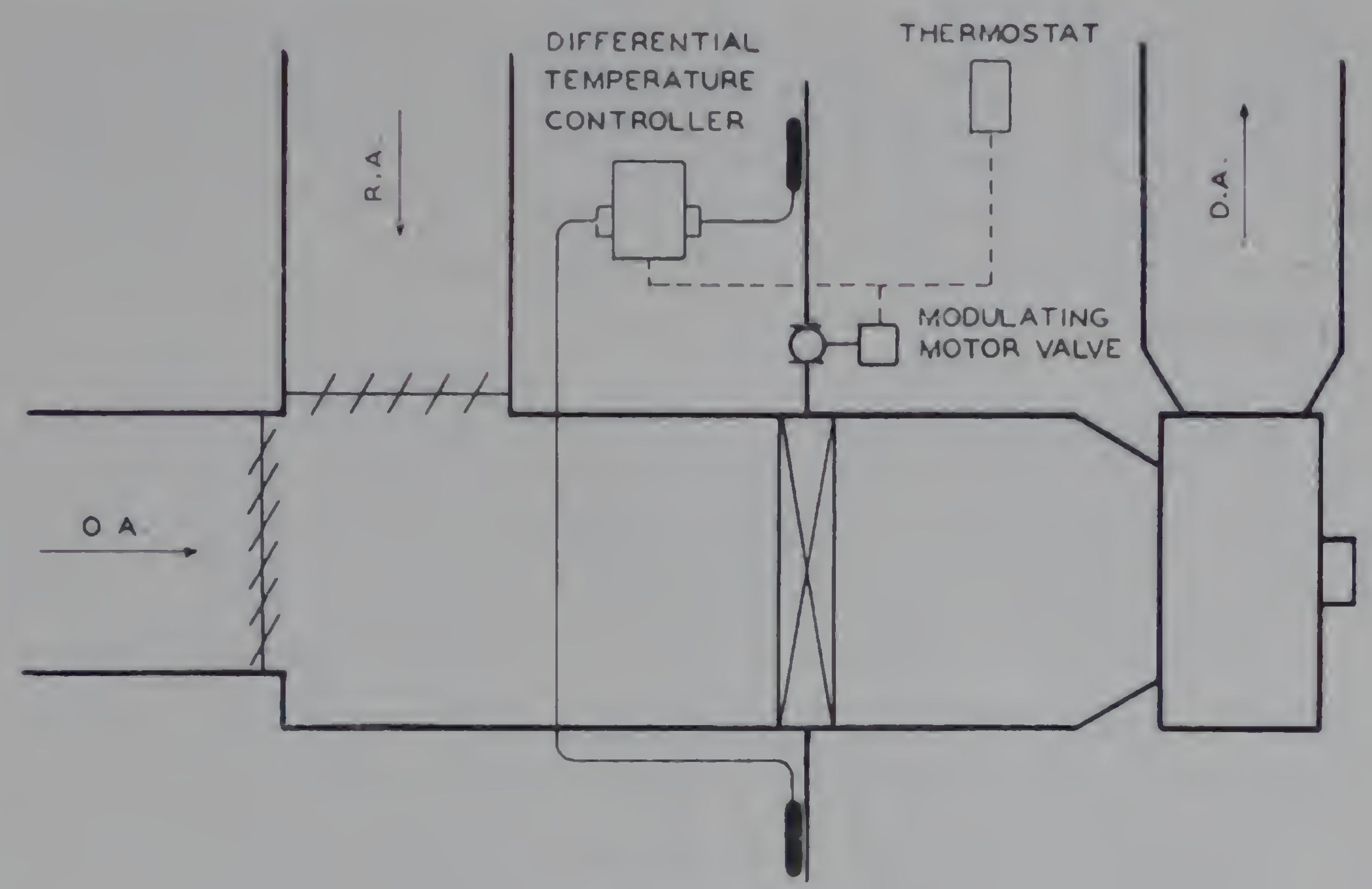


Figure 9

The temperature rise of the water through the coil can be controlled and a considerable saving effected by the use of a differential temperature controller to limit the quantity of water flowing through the coil. Such an arrangement is shown in Fig. 9. The differential temperature controller can be set up, for instance, to maintain a constant difference of temperature between supply and discharge of, say, 10°. If the thermostat calls for the valve to open, the valve will then be controlled by the differential temperature controller in order to maintain this temperature rise. Thus, under light load conditions the valve will be throttled off and less water will be used without sacrificing a great deal in the way of cooling capacity. Likewise, when sudden changes of load occur, such as on a pick-up period, the flow of water to the coil will be throttled so as to prevent unnecessary wasting of water. The motorized valve in this case becomes a modulating valve and the differential temperature control is of the modulating type. The thermostat operates in a two-position manner so that the valve is either closed or is being controlled by the differential temperature controller to admit the proper amount of water to the coil.

CONTROL OF DIRECT EXPANSION COOLING SYSTEMS

The problem in the case of the direct expansion cooling system again becomes that of balancing the control of latent heat removal against the control of sensible heat removal. The direct expansion system provides many possibilities not found with the cold water cooling just discussed and a clear understanding of the principles involved makes it possible to choose controls that will take full advantage of the inherent features of the system.

It has been shown that low coil temperatures produce maximum dehumidification. If this is so, why not design a system to operate at the lowest possible coil temperature at all times? Why attempt to control the dehumidifying effect?

The answer is found in the economy of operation.

1. **It is costly to run a system that is designed to operate on a low coil temperature. In the mechanical refrigeration system the number of BTU's of heat removed per H.P. of input decreases very sharply as the suction pressure drops. The operating efficiency becomes less at low suction pressures and low coil temperatures. (See Fig. 10).**
2. **It is costly because the removal of latent heat in excess of requirements is uneconomical and produces no added comfort benefits.**

CONTROL OF CENTRAL FAN COOLING SYSTEMS

The following is a typical chart showing variations in Cooling Effect Per Horsepower Input of a refrigeration system under different conditions of suction pressure. This chart is plotted for F12, but similar comparisons may be made for other refrigerants and compressor capacities.

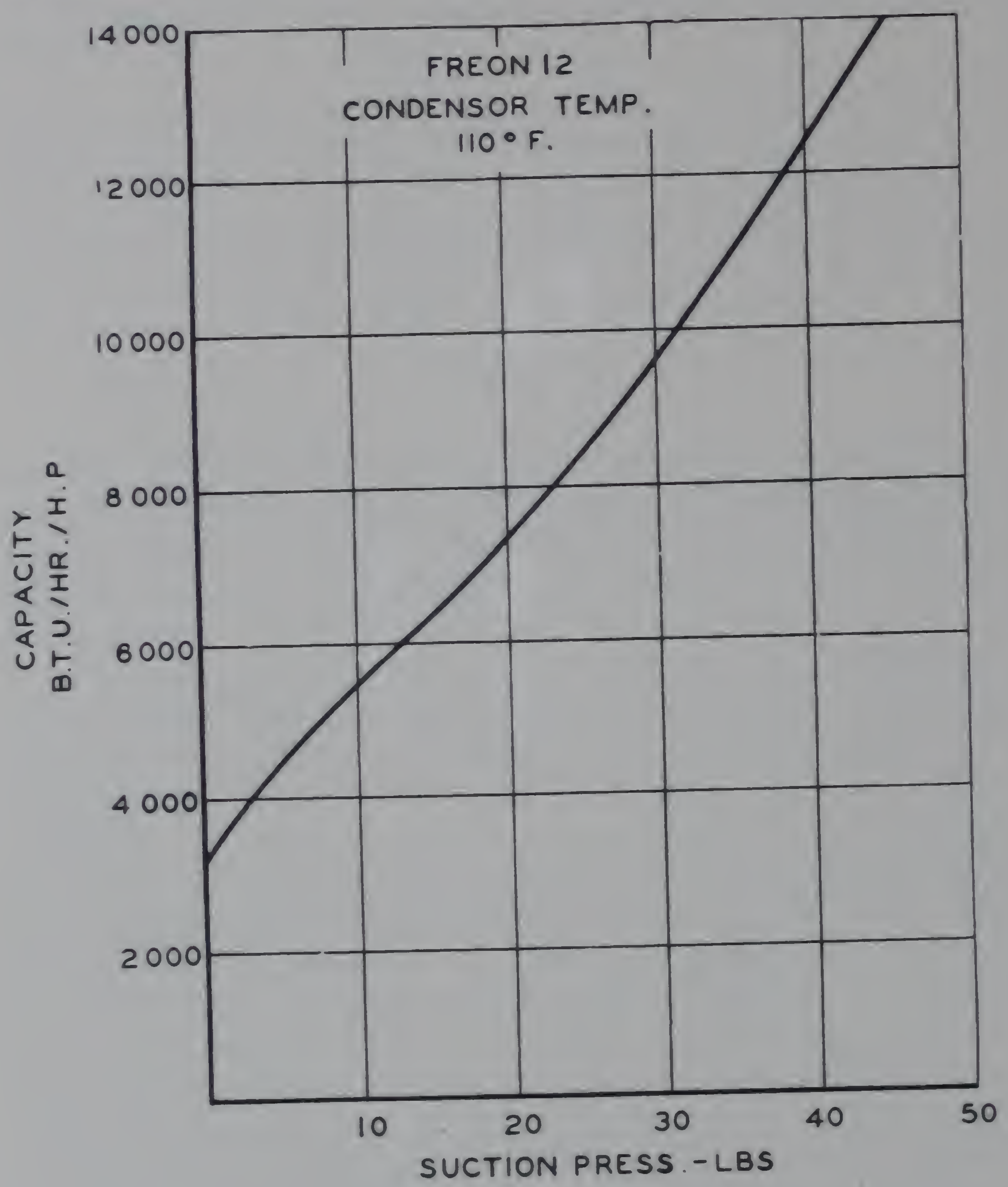


Figure 10

Referring to the chart it can be seen that definite control over coil temperatures should be maintained to prevent costly waste of power and at the same time insure adequate dehumidification when necessary.

Fortunately, there are certain basic characteristics of a refrigerating system that permit us to do this rather easily.

1. The coil temperature bears a direct relation to the suction pressure.
2. The suction pressure is determined by the relation of the load on the low side (the coil) as balanced against the capacity of the high side (refrigerating machine).
3. A decrease in the volume of air flowing over the coil decreases the load on the coil and therefore causes the suction pressure to drop, giving a lower coil temperature. Conversely, an increase in the air volume over the coil gives a higher coil temperature.
4. A decrease in the total amount of coil area on the system causes a decrease in load and a drop in suction pressure resulting in lower coil temperature. An increase in the total amount of coil surface results in a higher coil temperature. This principle is utilized in the Modutron System.
5. A decrease in the capacity of the refrigerating machine results in an increase in suction pressure and a higher coil temperature. An increase in machine capacity results in a lower coil temperature.

Some of the most common ways of effecting changes in suction pressure and thereby regulating the dehumidifying capacity of a direct expansion system are:

Variable Coil Area Control

Perhaps the most satisfactory means of capacity reduction is obtained with the "Modutron" control system. The Modutron provides for the variation of liquid flow to the direct expansion coil and in effect changes the superheat at the outlet of the coil in response to changes in room conditions. This means that the effective coil area is cut down as the cooling requirements drop off, resulting in a desirable reduction in coil temperature under light load which in turn produces better relative humidity conditions.

Two-Speed Compressors

Operating suction pressure can be changed by switching a compressor from one speed to the other.

Multiple Compressor Installations

Again the capacity, and hence the suction pressure, can be changed by controlling the number of units operating at a given time.

Compressor By-Pass Valves

Frequently a refrigerating machine may be equipped with by-pass valve or clearance pocket control that will provide a means of automatically reducing the capacity of the machine.

Variable Speed Compressors

Compressors with an electric drive of the variable speed type or compressors driven by gas engines generally provide a means of changing the speed, and hence the capacity of the machine, with modulating action.

Double Coil or Multiple Coil Systems

In such installations the direct expansion coil which is located in the duct is made in two sections independently controlled so that either one section or both can be made effective. It is obvious that if we operate on only one-half of the coil the load on the machine in terms of BTU/min. will be materially less than the load where the entire coil surface is used. This means that lower suction pressures will prevail when operating on half coil area.

Variable Air Volume

An installation which through the adjustment of dampers provides a means of changing the volume of air passing over the coil does to some extent change the load on the coil and therefore the coil temperature. This principle is involved in by-pass systems.

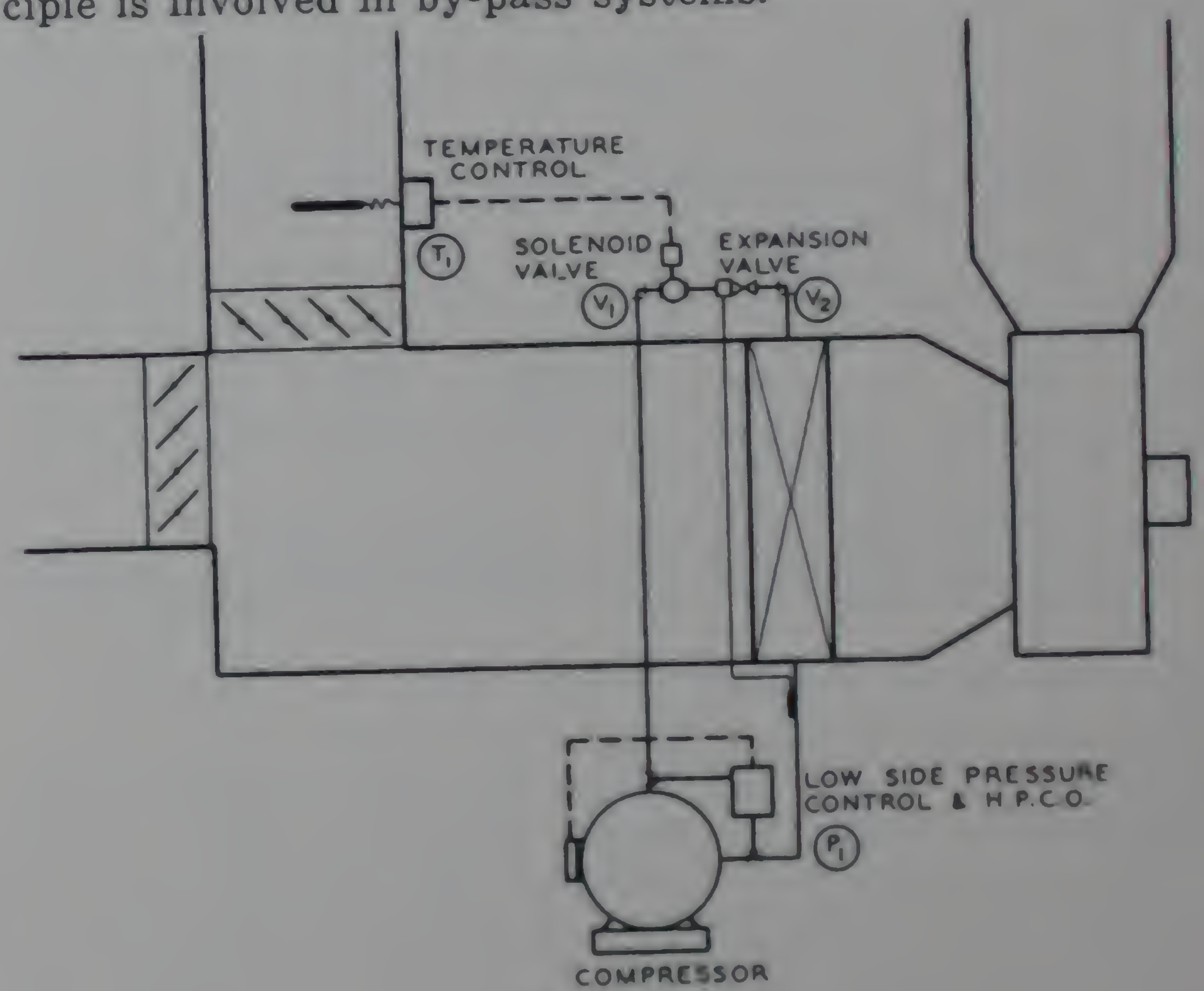


Figure 11

Fig. 11 illustrates a simple type of direct expansion cooling installation utilizing a single pass system with a single coil section. The flow of refrigerant to the coil is

CONTROL OF CENTRAL FAN COOLING SYSTEMS

controlled by a solenoid valve. The solenoid is opened and closed upon demand of a thermostat.

With this type of system the suction pressure is allowed to assume any value determined by the load at a given instant. It can be seen that coil temperatures will automatically assume a higher value as load conditions rise. The only variation in instantaneous load on this type of system is that which comes from a reduction in the entering wet bulb value.

Although the control sequence as illustrated shows the solenoid valve alone under thermostatic control, it is common practice to de-energize the compressor circuit simultaneously. If this is not provided for, the compressor is operated by a combination high pressure cutout and suction pressure controller. The low pressure control is generally set to cut out at a point which will prevent frost from forming on the coil, and to cut in at a much higher point.

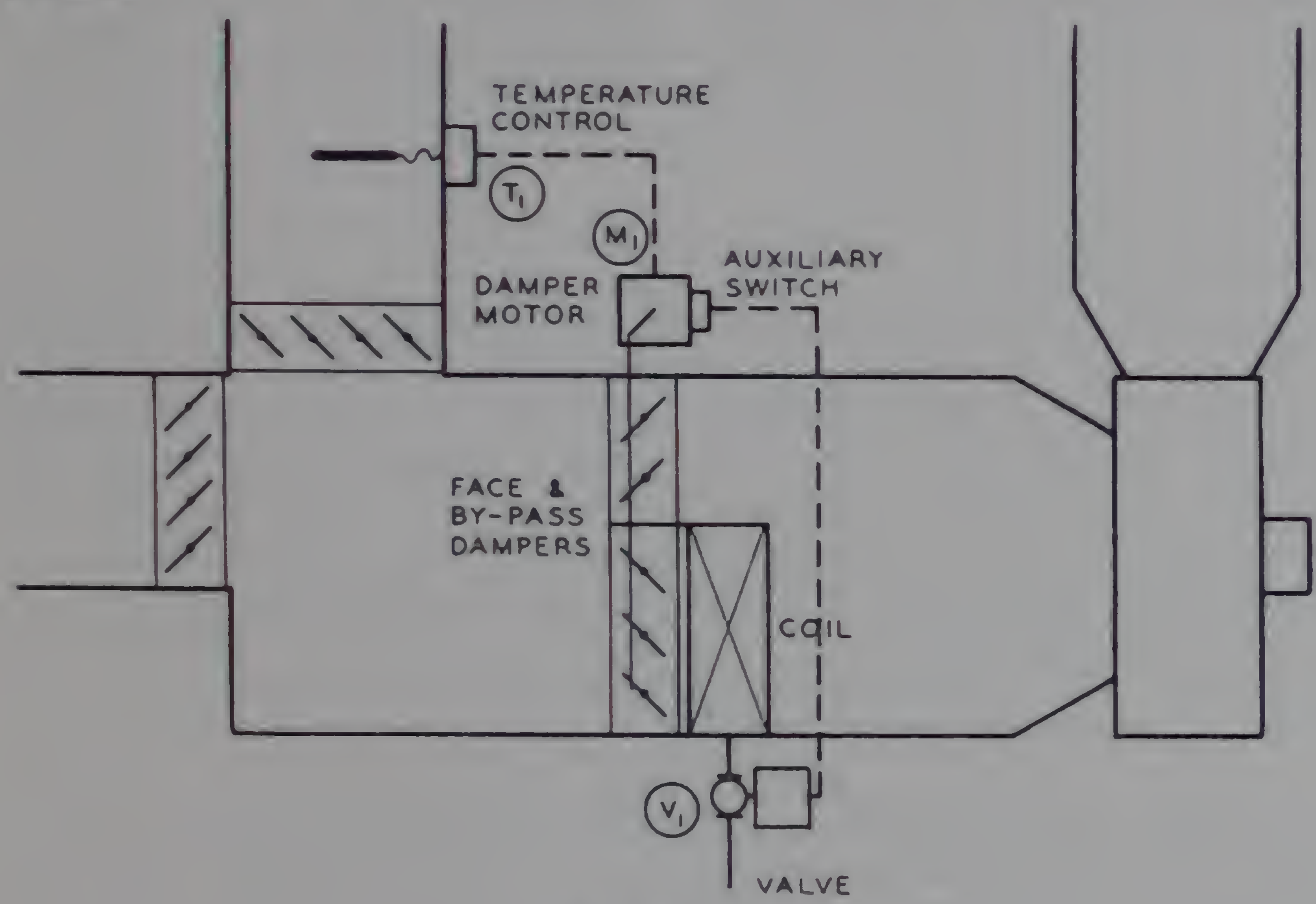


Figure 12

Fig. 12 illustrates a face and by-pass damper installation wherein the temperatures are maintained by positioning dampers to regulate the amount of air flow through the coil. This system provides for gradually changing the temperature of the air discharged and is therefore a considerable improvement over the simple system shown previously. Discharge air temperatures will remain constant at the proper point for meeting the load requirements whereas the "on-off" system results in alternate discharge of first cold and then warm air.

It is also true that under light sensible load conditions, the load on the coil will be reduced causing a reduction in coil temperature and therefore the system should permit lower relative humidities than the simple single coil system. The minimum coil temperature will be limited by the point at which frost will form on the coil and therefore it is necessary to cut off the coil on the refrigerating machine as the face damper approaches the closed position. This is frequently done by the use of an auxiliary switch associated with the motor which will act to close a solenoid valve. A suction pressure control on the refrigerating machine will cut off the compressor when the valve closes. This control is set so as to stop the machine whenever the suction pressure reaches a point which would be indicative of a frosting coil. It should be noted that the reduction in air volume on the coil also tends to limit the point at which frost will form on the coil.

1. With this arrangement of equipment, substantially constant temperatures are maintained in the discharge from the system and the noticeable ups and downs of "on-off" control are eliminated. It is also true that this system provides for more latent cooling under light sensible load conditions by reason of the slight reduction in coil temperature that takes place due to the restricted air volume.

Two Speed Compressor Control

Fig. 13 illustrates control of a system wherein it is possible to change the capacity of the high side of the refrigerating circuit. This provides a very flexible system wherein both temperature and humidity may be individually regulated up to the point where artificial reheat becomes necessary.

Since varying the capacity of the refrigeration equipment provides a means of changing the coil temperature, the S/L ratio may be changed to meet varying conditions.

A two-stage thermostat is arranged to energize the compressor starter on an initial rise in temperature. A high and low pressure limit control is also included in this circuit. If the humidity is high at the moment of starting, the humidity control will establish a second circuit to energize a speed changing relay which will cause the machine to operate on high speed, thus providing a lower coil temperature.

The machine will operate at one-half speed under low latent heat load conditions and will be transferred to high speed only when the relative humidity exceeds a predetermined maximum.

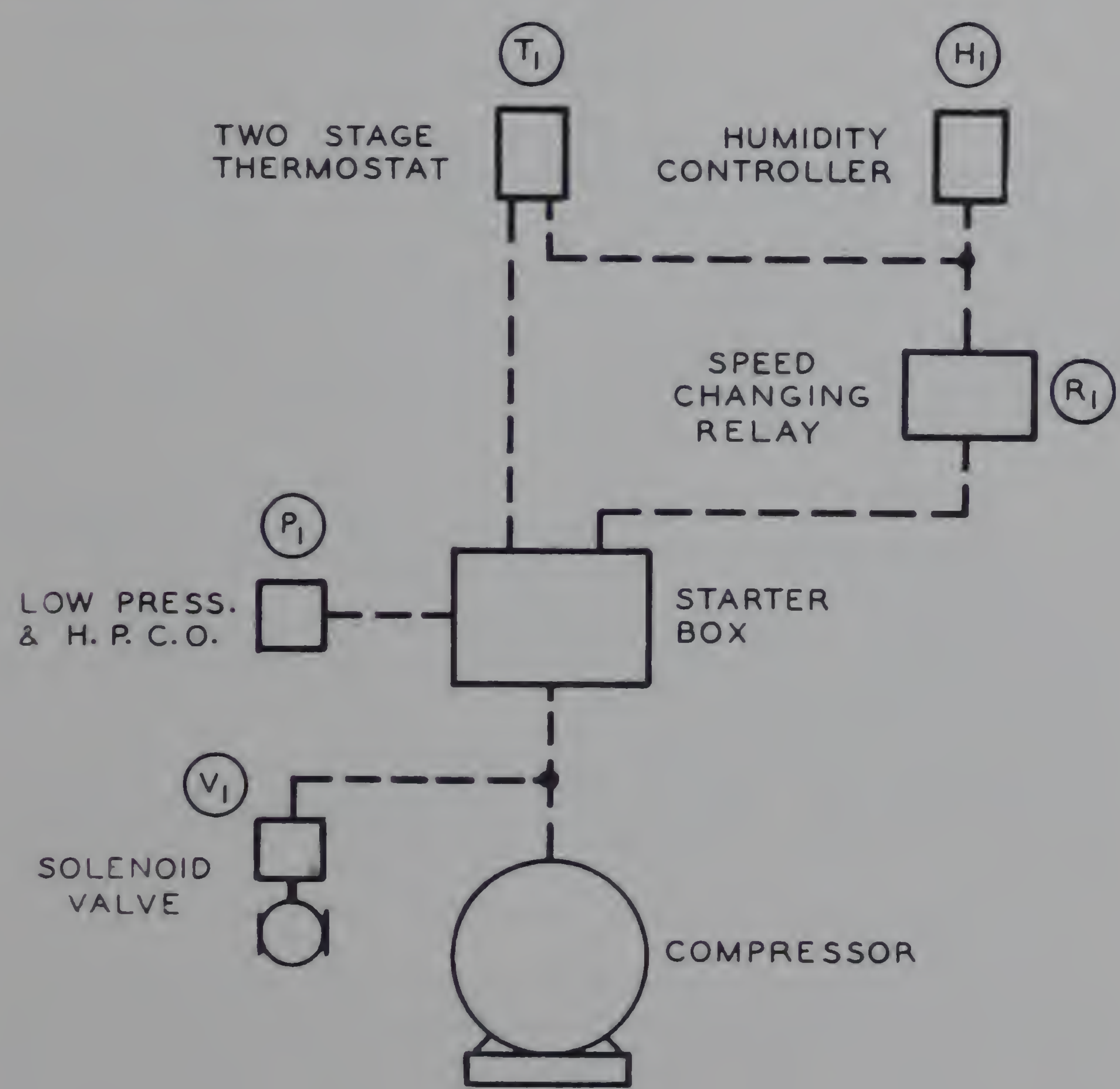


Figure 13

It is to be expected that the refrigerating equipment will not be sized to handle the maximum or design sensible load conditions when operating on low speed. It is therefore necessary to operate the compressor at full capacity whenever dry bulb temperatures cannot be maintained. This function is accomplished by the control action of the second stage of the thermostat.

The same arrangement of control equipment may be employed where two separate compressors are installed with liquid and suction lines connected in parallel.

CONTROL OF CENTRAL FAN COOLING SYSTEMS

An identical control sequence may be installed to regulate the operation of compressors equipped with by-pass valves or other similar means of machine capacity reduction.

1. **In providing independent control of both temperature and humidity within the available limits, this system accomplishes definite economies. Compressor efficiencies are increased when latent load conditions are light and at no time is the period or capacity of the heavy equipment operation increased to an unnecessary point.**

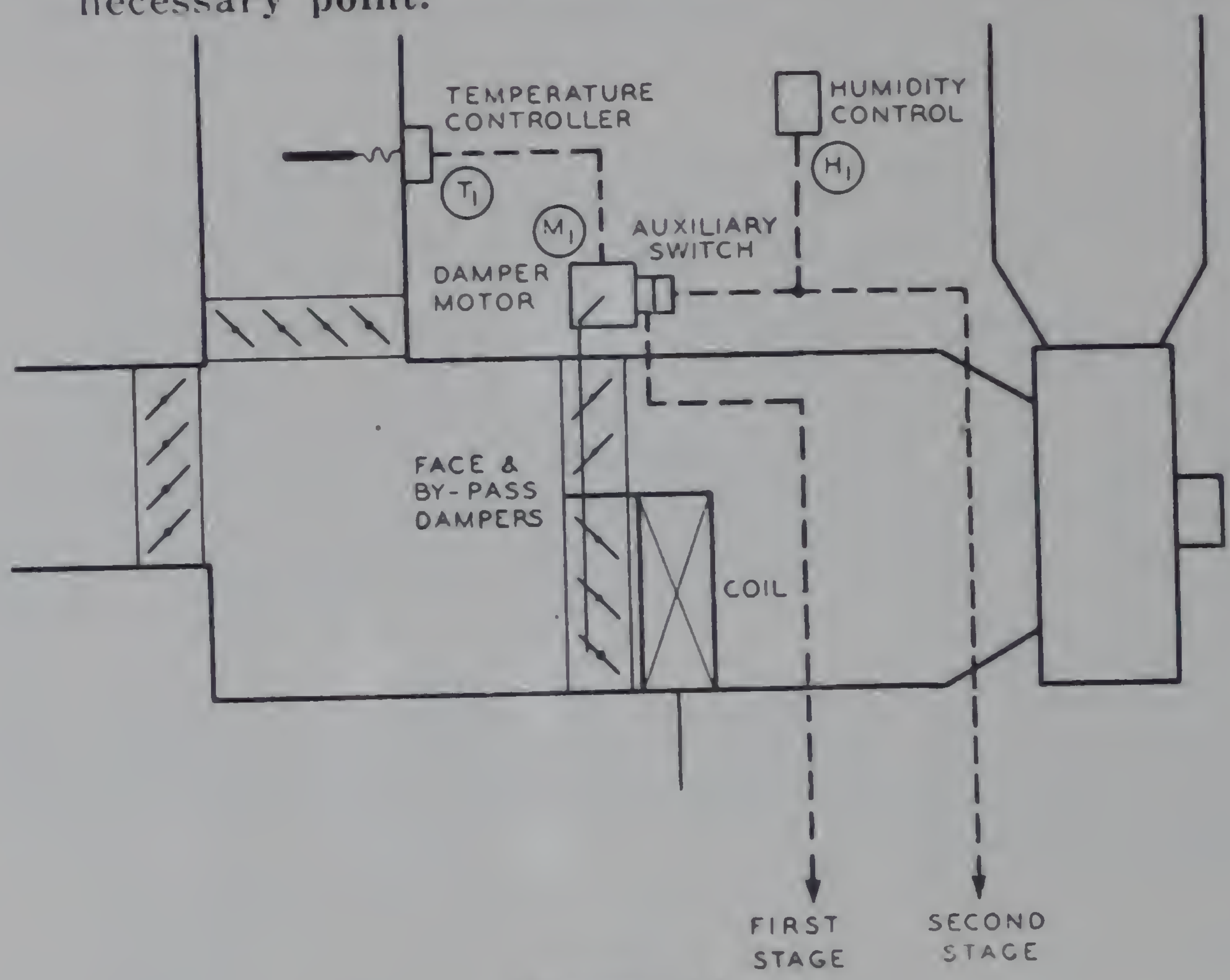


Figure 14

Fig. 14 illustrates a system wherein the coil is normally operating continuously and the delivered air temperature is determined by the position of face and by-pass dampers. Means are provided to shut off the machine completely when the face damper reaches a closed position.

When the refrigerating equipment is operating, its capacity will be determined by relative humidity conditions. This system therefore combines the advantages discussed under Fig. 12 and Fig. 13.

1. **With this system the compressor equipment will be operated at a higher suction pressure under light load conditions and at the same time an accurate regulation of delivered air temperatures may be maintained through the throttling effect of the face and by-pass dampers.**

There is no essential difference in the control sequence if a return or outside air by-pass is utilized in place of the face and by-pass shown.

Limitations of Two-Stage Thermostats

It has in many cases been common practice to install a simple two-stage thermostat to control two-speed compressors. Without the use of a humidity control in the circuit such as shown in Fig. 13, this system may result in unsatisfactory conditions.

As the load becomes lighter, the sensible load decreases and the machine will tend to operate most of the time on low speed or half capacity. This means that the coil temperatures under light sensible load conditions will be high. Actually, under light sensible load conditions, the latent heat load often increases with respect to sensible heat giving a low S/L ratio. This will result in high relative humidities so that in general it is better to operate at a low coil temperature during light sensible load conditions than it is at a high coil temperature. Obviously, this system just described would operate just the reverse of the recommended practice.

Another similar type of system are those systems where a multiple step controller is controlled by a dry bulb thermostat to throttle the capacity of the machine with changes in dry bulb temperature. Again this permits higher coil temperatures under light sensible load conditions which is undesirable if a humidity control is not used as a limiting device.

If a two-stage thermostat is used to control solenoid valves on split direct expansion coils, it is obvious that under light sensible load conditions half of the coil will be used and that therefore the load on the low side is less resulting in lower suction pressures. This type of system, therefore, gives low coil temperatures under light sensible load conditions and will not result in an upward drift of relative humidities if the S/L ratio decreases.

This statement is also true of a thermostat controlling a multiple step controller which is used to control solenoid valves on several banks of direct expansion cooling coils since when fewer coils are operating under light sensible load, the suction pressure decreases, as is desirable.

CONTROL OF REFRIGERATION EQUIPMENT

In the previous discussions the use of a combination high and low pressure cutout has been mentioned but the functions of this controller have not been discussed in detail.

The operation of refrigeration machinery in connection with air-conditioning varies somewhat from typical commercial applications because of the unusual conditions arising due to the rapid movement of air over the heat exchanger surface.

Suction Pressure Control

The low pressure control serves the purpose of limiting the suction pressure and thus preventing the machine from pulling a low enough pressure to cause the coil to freeze. The rapid air circulation through the coil will quickly raise the suction pressure by evaporating the refrigerant left in the coil. Therefore a wide differential should be employed on the suction pressure control to prevent short cycling.

High Pressure Cutout

A high pressure cutout is also used to prevent the head pressure from building up to an excessive point as a result of condenser water failure or other causes. Instead of using a separate high pressure cutout this feature is generally provided by a combination pressure control providing the functions of both low pressure protection and high pressure cutout.

The conventional high pressure cutout on an air-conditioning system will protect the machine in event an excessive pressure is reached, but it will not prevent starting of the compressor under a condition where the head pressure is nearly up to the cutout point. For example: The high pressure cutout may be set to cut out at 200 lbs. per sq. in. If the head pressure were up to 190 lbs. per sq. in. it would be possible for someone to stop and immediately restart the compressor against this wide pressure difference, resulting in an abnormal load.

The Polartron*

There is now available a new refrigeration compressor control, "The Polartron", which definitely prevents the starting of the compressor under any circumstances until the head pressure has dropped to whatever cut-in point is chosen. It also prevents starting until the low side pressure rises to the normal cut-in point. This means that when the machine stops from any cause the control prevents restarting until the pressure differential across the compressor has narrowed to the desired limits, thus eliminating an abnormal load, which is an unknown factor on the ordinary installation. In addition, the control provides thermal overload protection and a convenient junction for wiring.

Multiple Compressor Control

On large multiple systems very frequently a battery of individual compressors is used in preference to one large central machine. The purpose of using a number of smaller units instead of one large unit is found in the flexibility of such an arrangement in being adaptable to varying loads.

*Trade Mark

CONTROL OF CENTRAL FAN COOLING SYSTEMS

In controlling a battery of compressors of this type primary control very frequently is accomplished from the suction pressure. In other words, several compressors may be tied together with common suction and liquid headers. It then becomes desirable to measure the suction pressure and control the number of machines operating in such a way as to maintain a constant suction pressure. Care must be taken in choosing the cut-in and cut-out pressure of each compressor to prevent short cycling of any machine.

On indirect systems where refrigeration is used to control the temperature of water supplied to the air-conditioning system, the control of the compressors generally takes place from the temperature of the water storage. On direct expansion systems the sequence of operation of the compressor may also be controlled from room conditions by temperature or humidity controls.

In either event, the control sequences required are similar, and the multiple step controller provides a simple means of controlling multiple compressor operation.

Sequence Control

The step controller is a control unit which provides for successive opening and closing of electric circuits in response to the demand of a modulating type controller. With this type of control it is possible to operate multiple power units in a definite sequence so that they may be energized and de-energized in direct proportion to load variations.

Definite precautions must be taken to prevent the possibility of all equipment being energized simultaneously following a failure in power which occurs at a time when the system has been brought up to maximum capacity.

If no particular means of protection were provided and a power failure should occur when all motor units were in operation, these motors would be thrown across the line simultaneously upon a resumption of power and the electric supply circuit would be dangerously overloaded.

A system is available which provides protection against such an occurrence as this, and should always be installed where the step controller is used in the control of multiple compressor installations. With this system, a modulating type Pressuretrol or thermostat positions the step controller to cause any required number of compressors to operate. However, in the event that a power failure occurs, on the resumption of power service no current is allowed to pass through the starter coils and therefore none of the compressors will run immediately. A relay included in the circuit causes the step controller to return to the starting position cutting off the switches one by one. When it has reached the starting position, the relay will provide power to the starter coil circuit and the motor will then be positioned under command of the modulating control so as to cut on successive compressor motors one at a time until it reaches the stage demanded by the controller.

Fig. 15 shows the schematic arrangement of control equipment for step control of multiple compressors. A detailed wiring connection diagram for this system is shown on page 20 of Section Three.

It is not always necessary to have a large number of compressors in order to obtain numerous steps of capacity and flexibility in adapting the capacity to the load. It is possible with the use of the multiple step controller to obtain additional stages of operation by re-connecting the compressors in progressive stages or by re-connecting two-speed compressors. For instance, if three compressors were available of 5 H.P., 7½ H.P., and 10 H.P. capacity, a total of seven stages of operation can be obtained, as follows:

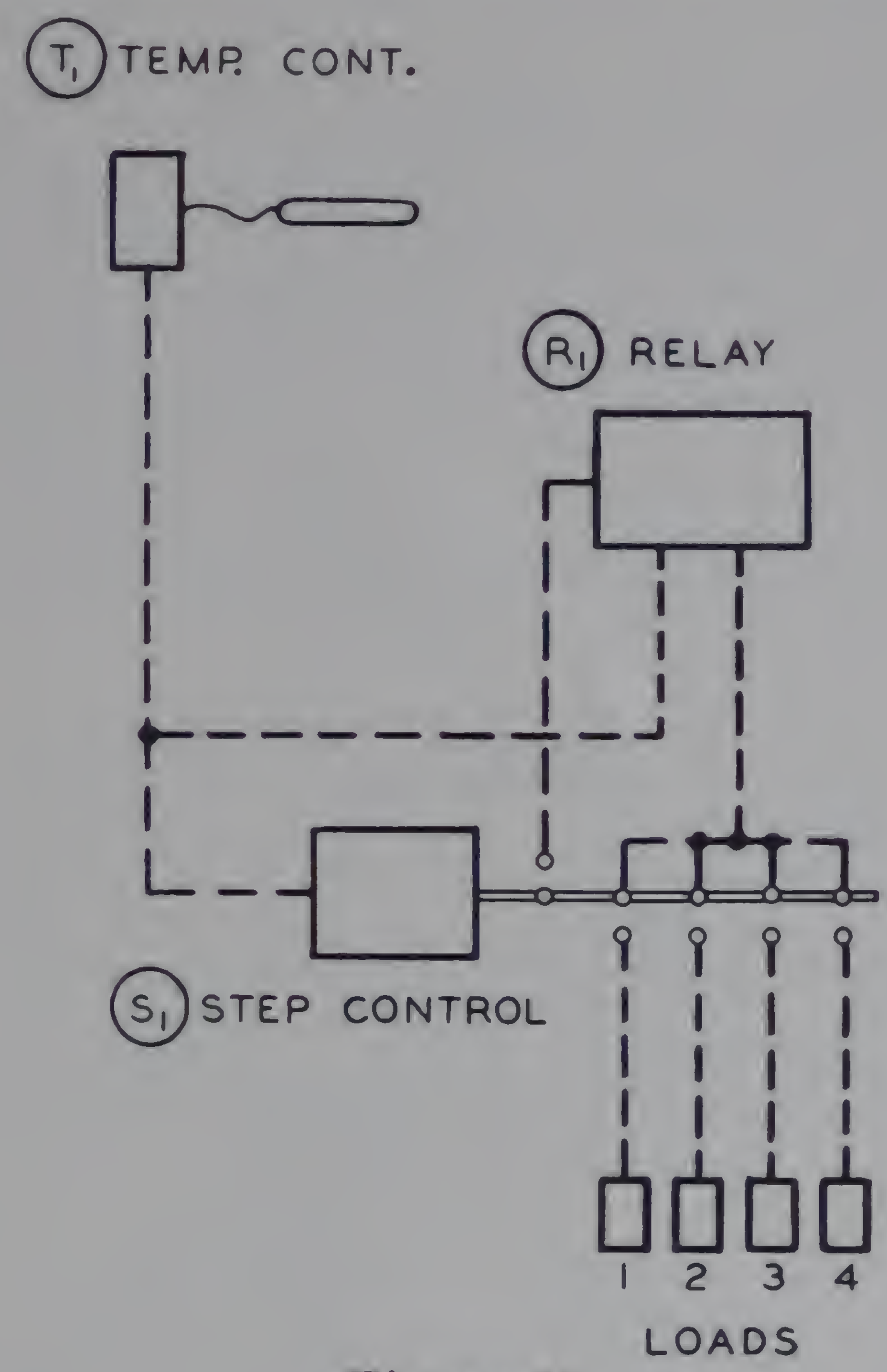


Figure 15

Stage No. 1—5 H.P. compressor
Stage No. 2—7½ H.P. compressor
Stage No. 3—10 H.P. compressor
Stage No. 4—5 H.P. + 7½ H.P. = 12½ H.P.
Stage No. 5—5 H.P. + 10 H.P. = 15 H.P.
Stage No. 6—7½ H.P. + 10 H.P. = 17½ H.P.
Stage No. 7—5 H.P. + 7½ H.P. + 10 H.P. = 22½ H.P.

INTERNAL COMBUSTION ENGINES

Where internal combustion engines are used as the power unit for refrigerating machinery, control may be obtained through throttling the engine capacity.

Throttle Control

A modulating motor can be mounted directly on the engine and mechanically connected to the throttle arm. This motor reacting to gradual changes in suction pressure, humidity, etc., will reposition the engine throttle to reduce the equipment speed as the load decreases. An alternate arrangement of equipment provides for throttle control by an engine governor which is reset by the movement of the modulating motor.

Minimum Speed

In controlling the speed of internal combustion engines, precautions must be taken to prevent throttling below a certain idling speed. This minimum engine speed is determined by the design of the particular equipment under consideration. To prevent the engine from operating at too low a speed, it is desirable to utilize a positive acting snap switch on the modulating motor which will cause the ignition circuit to the engine to break when the motor has moved to a fixed point.

Automatic Starting

When the system is under automatic control, it is therefore frequently necessary to provide a means of automatically restarting the engine after a period of complete shutdown. This may be accomplished by allowing the switch on the modulating motor to re-establish the starting circuit when the motor calls for a proper operating speed.

CONTROL OF CENTRAL FAN COOLING SYSTEMS

Protection

Adequate protection against excessive head pressures must be provided. In the event that the engine is controlling from temperature, special precaution should also be taken to prevent extremely low suction pressures. These functions may be accomplished by a two-position control device for high pressure cutout and where low pressure protection is required, a modulating type pressure control can be used to good advantage since it provides for throttling the compressor speed to alleviate the low suction pressure condition and thereby eliminates the possibility of short cycling the power equipment.

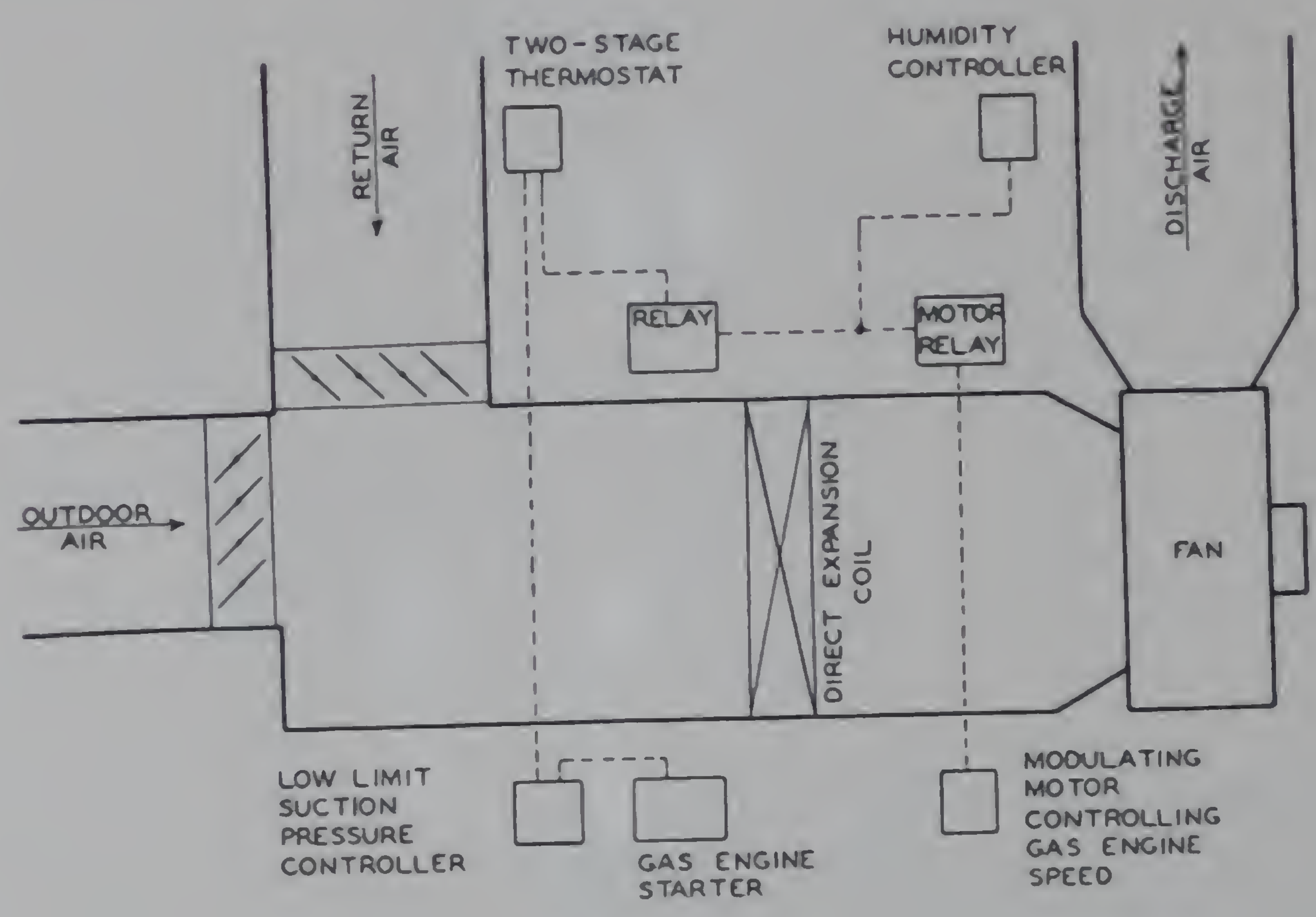


Fig. 16

Fig. 16 shows a typical gas engine control system. With this system, a two-stage thermostat acts to start the compressor on a small rise in temperature thus allowing a modulating type humidity controller to regulate the speed of the engine in response to relative humidity variations. The equipment will operate at greater capacity and provide a lower coil temperature as the humidity rises.

If the temperature continues to rise, the thermostat will cause the engine to operate at high speed regardless of the action of the humidity controller.

Should the temperature drop below a predetermined minimum, the thermostat will cause the engine to shut down. Likewise, should the pressure in the suction line from the coil drop to a predetermined minimum, the engine will be shut down.

It is possible to adapt the face and by-pass damper system to gas engine installations in such a manner that room air temperature will be maintained at all times and independent control of coil temperatures will be accomplished through a humidity control which will reposition the motor driving the throttle arm of the engine.

THE CONTROL OF AIR WASHER SYSTEMS

There is a fundamental difference between the operation of air washers and closed coil type systems. This difference is found in the fact that air leaving the conditioning chamber of an air washer is always very nearly or completely saturated. Air leaving a closed coil, however, may be saturated to a far less extent depending upon coil temperatures and moisture conditions of air entering the system.

In the washer type system the temperature of the water in the sprays determines the dewpoint temperature of the air leaving the washer chamber.

Dewpoint Control

In the closed coil system during periods when there is a light latent heat load and when the dewpoint of the air passing through the coil is actually below the coil surface temperature, no latent heat is removed or added to the air in the rooms. In a washer since the air always leaves at a dewpoint determined by the water temperature, it is possible to maintain an approximately constant dewpoint at all times. The effect of this condition is the maintenance of constant relative humidity under substantially constant S/L load ratios.

The air washer is in continuous operation and a by-pass around the conditioning chamber provides a means of maintaining discharge dry bulb temperatures at the proper level. A modulating thermostat measures the temperature of the air leaving the washer chamber and controls a modulating three-way mixing valve to proportion the relative amounts of refrigerated and by-passed water in accordance with changes in the temperature of the air leaving the chamber. The pump as illustrated provides a means for circulating water through the system.

An increase in temperature of the air leaving the washer will cause the valve to reposition in such a manner that a greater proportion of cold water will be admitted to the sprays thus lowering the resultant dewpoint. This type of control is referred to as dewpoint control since the dewpoint temperature, dry bulb temperature, and wet bulb temperature leaving the washer are all at practically the same level.

With this type of system, the S/L ratio (the relation between latent heat removed and sensible heat removed from the space) remains constant at all times for a given dry bulb temperature and relative humidity.

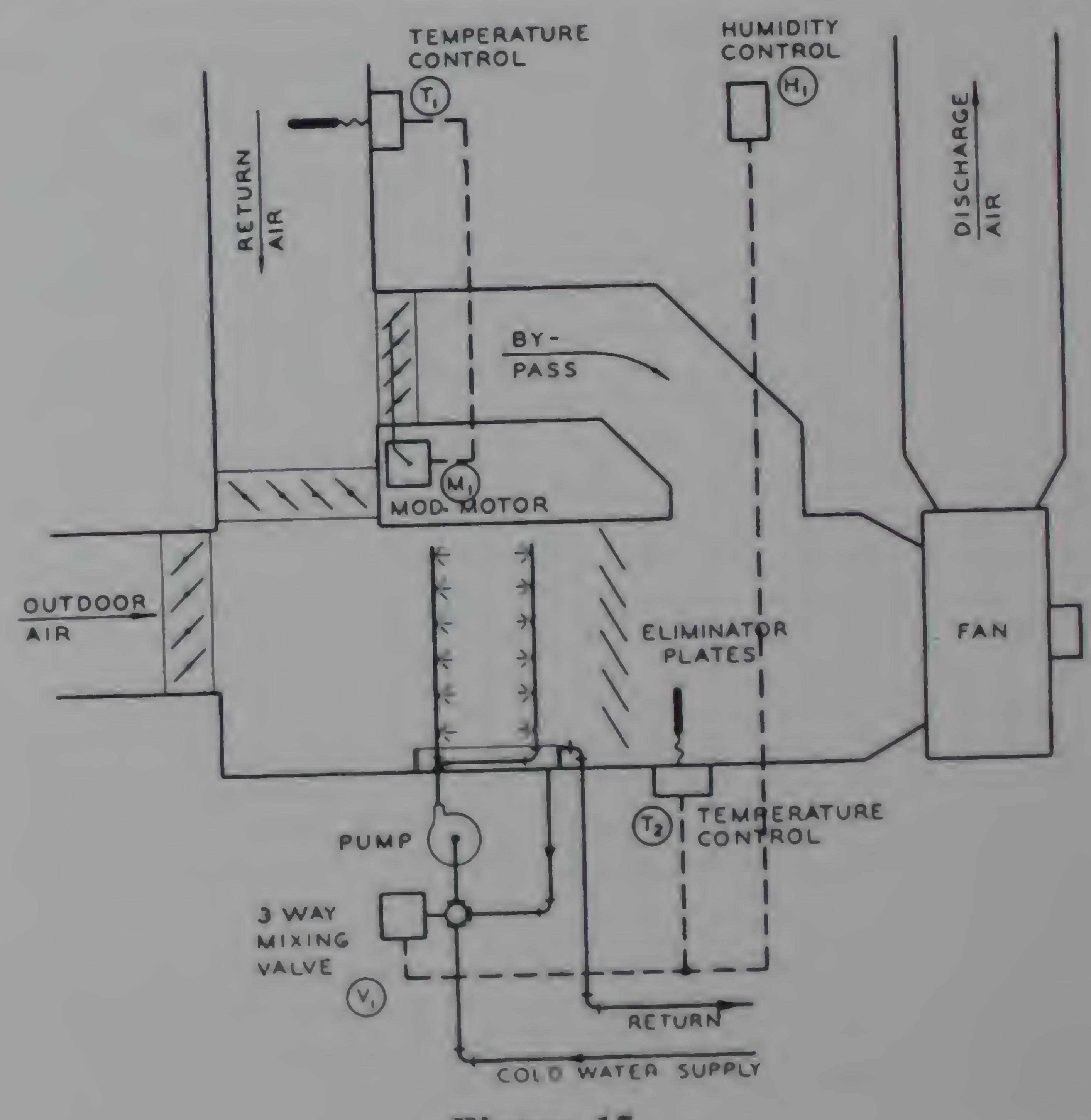


Figure 17

The application of "Dewpoint Control" is illustrated in Fig. 17.

It is apparent that additional economies can be obtained if the dewpoint temperature is raised during periods when the latent heat load is low. This function can be accomplished by using a humidity control to reset the control point of the dewpoint thermostat in such a manner that:

CONTROL OF CENTRAL FAN COOLING SYSTEMS

1. Low dewpoint temperature will be maintained when relative humidities are high.
2. A higher dewpoint temperature will be maintained when relative humidities are low.

This additional feature prevents the unnecessary removal of latent heat.

DEHUMIDIFYING SYSTEMS

Inasmuch as a great proportion of the total load on a cooling cycle is made up of moisture removal loads, systems are very widely installed which provide for moisture removing functions rather than a cooling result. Two popular types of installations working on this principle are:

1. **Silica Gel Dehumidifier.**
2. **The dehumidifying spray type of system.**

Silica Gel

With the Silica Gel system the air is passed through Gel beds which absorb the moisture from the air. Air is then usually passed through a cooling coil which will provide the required amount of sensible cooling. These Gel beds must be reactivated periodically and this is commonly done by alternating between two Gel beds, reactivating one while the other is being used.

Spray Dehumidifier

The dehumidifying spray type of installation consists of a solution of lithium chloride or other chemical solutions having an affinity for moisture. The solution is concentrated to such an extent that it has an affinity for moisture in the air, and the solution sprayed in the path of the air will absorb moisture. Again the air is generally passed through cooling coils which provide for some sensible cooling or the spray may itself be cooled. The solution when it leaves the sprays is passed at least in part through a concentrator which boils off some of the moisture collected and returns the solution at its original concentration.

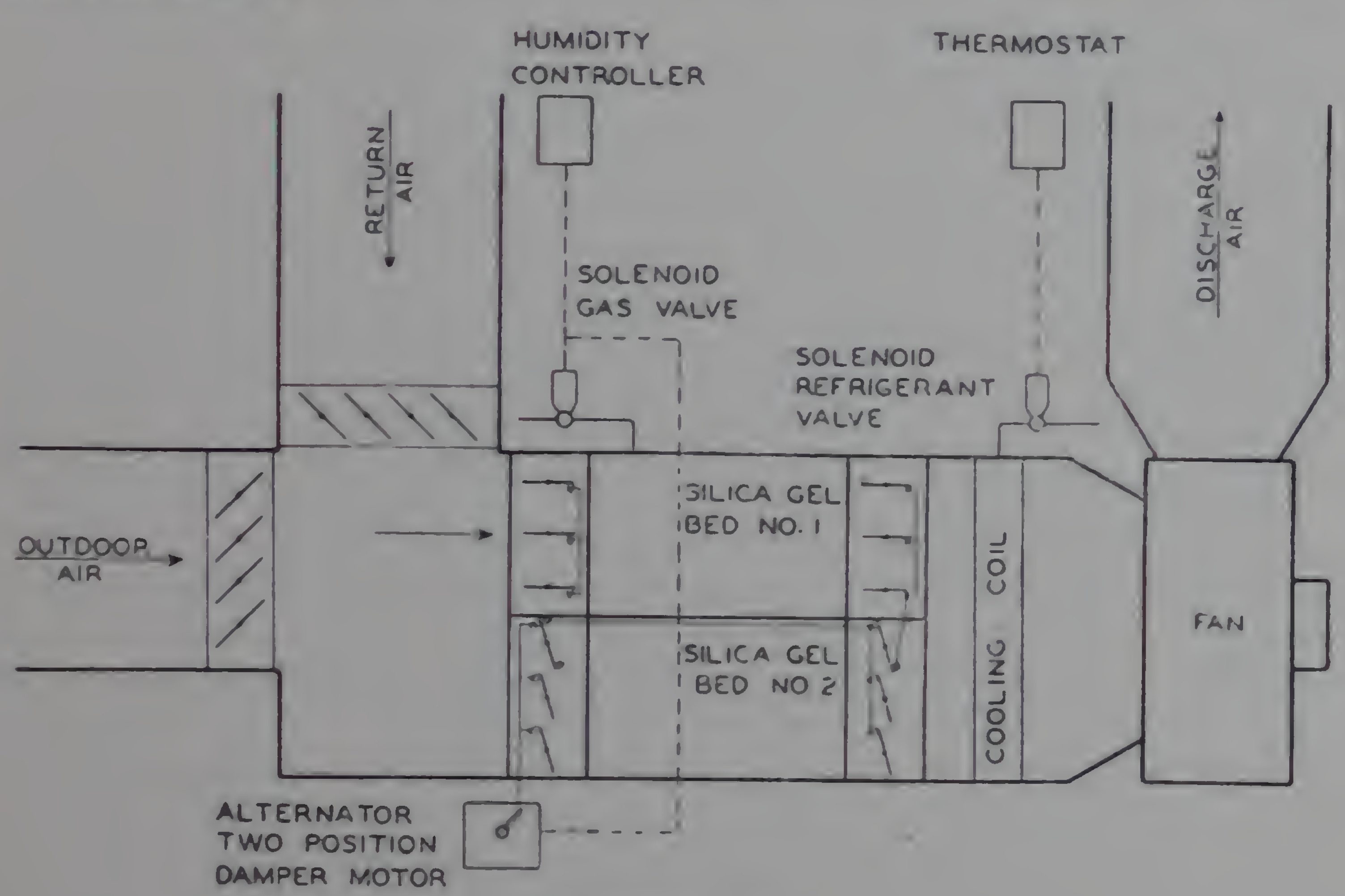


Figure 18

Fig. 18 shows a typical control for a dehumidifying systems. The particular illustration shows a Silica Gel system. The humidity control places the system in operation, gas is admitted to the reactivating chamber and an alternating motor is put into operation. If the cooling coil is a water or brine coil rather than a direct expansion coil as shown, it is generally controlled by a thermostat of the modulating type which positions the motorized valve, throttling the supply of water to the coil.

Generally in an installation of this kind the humidity controller is set to a lower value than could be used on a strictly cooling installation. The reduction in relative humidity permits the maintenance of higher dry bulb temperatures to get the same feeling of comfort.

APPLICATIONS REQUIRING REHEAT

Many of the systems described in this section have shown methods for the independent control of both temperature and humidity within the limitations of the air-conditioning system. Actually, however, the physical laws involved prevent the maintenance of definite temperatures and humidities under all load conditions unless some form of reheat is employed.

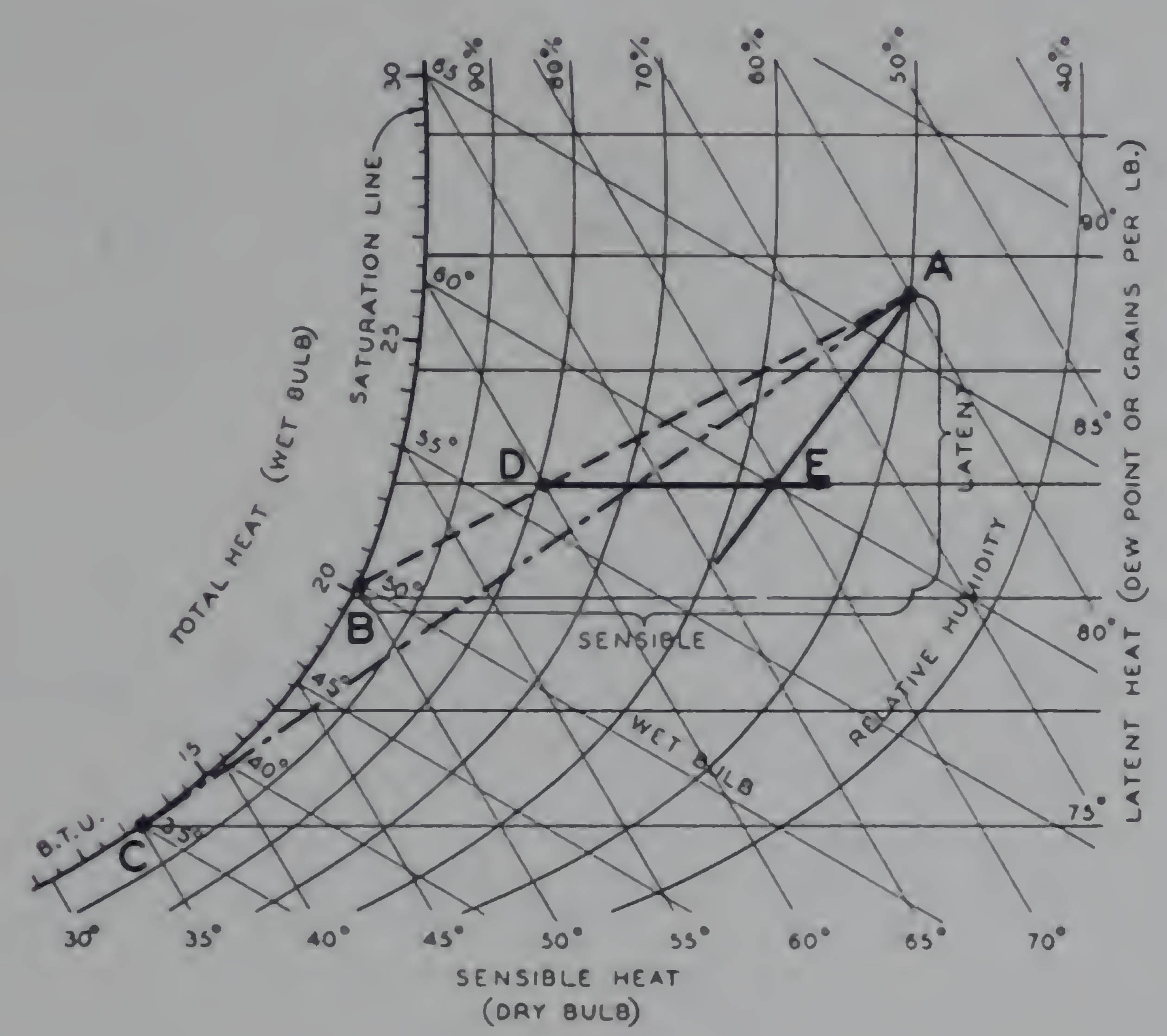


Figure 19

Fig. 19 provides a psychrometric illustration of the necessity for reheat on installations where both temperature and humidity must be maintained under varying load conditions. In this example the following facts are known:

1. **The desired space conditions are 80° and 50% R.H. (represented by point A).**
2. **The lowest available coil surface temperature is 50° (represented by point B on the saturation curve).**

From this information it is possible to determine that the desired conditions may be maintained for load conditions where the S/L ratio is 2 (see page 11 for detailed explanation).

This means that the air discharged from the conditioner unit using a 50° coil temperature will absorb one-half as much latent heat as sensible heat. Obviously, this ratio does not represent an exact sensible and latent B.T.U. heat removal, but merely a ratio between the two.

Should the load conditions change so that the S/L ratio becomes 3 it is obvious that it is necessary to remove only one-third as much latent heat as sensible heat to maintain the specified conditions. Operating at 50° coil temperature the unit would then deliver air which would absorb a greater amount of latent heat than necessary while removing enough sensible heat to maintain the desired conditions. This would result in lower humidity conditions than those specified. Normally this is not objectionable in comfort conditioning.

If, on the other hand, the S/L ratio should decrease to 1.5 it can be seen that it becomes necessary to remove two-thirds as much latent heat as sensible heat in order to maintain conditions as required. It is not possible to accomplish this with the equipment operating at a 50° F. coil temperature. One of two conditions will result:

1. **The relative humidity may be held at 50% but the tempertaure will be reduced below 80° F.**
2. **The temperature may be held at 80° F. but the relative humidity will rise above 50%.**

CONTROL OF CENTRAL FAN COOLING SYSTEMS

On many of the systems described in this section we have shown methods where both temperature and humidity could be controlled independently within the limitations of the system. Actually, however, physical laws involved prevent the maintenance of definite temperatures and humidities throughout all load conditions. We have already discussed the relation between the coil temperature and the ratio of sensible to latent heat removal.

Referring to Fig. 19, we have a problem of maintaining a temperature represented by point "A" at 80° and maintaining a relative humidity at 50%. If the lowest coil temperature available is 50° as represented by point "B" on the saturation curve, we can see that such air discharged into the room will remove just twice as much sensible heat as latent heat. In other words, the S/L ratio will be 2. As long as the S/L ratio is greater than 2, we can maintain the temperature and the humidity as required providing we have a means of raising the coil temperature.

However, under a condition where the S/L ratio is less than 2—in other words, where the loads were such that it would be necessary to remove more latent heat than as represented by one-half of the sensible heat removed, it would obviously be impossible to maintain relative humidity at 50% as required.

Even if we could lower the coil temperature, we would soon reach a condition where it would be impossible with any coil temperature to maintain the humidity as desired. This point is represented by the intersection of the straight line from point "A" drawn at a tangent to the saturation curve. Thus it can be seen that if we had a coil temperature of 35° represented by point "C" the resulting ratio between sensible and latent heat removal would be 1.5. In other words, we would remove 1 BTU of latent heat for every 1½ BTU's of sensible heat. Again, if the ratio between sensible and latent heat removed becomes smaller than this value, it is impossible with any coil temperature to maintain a dry bulb temperature of 80° and 50% relative humidity.

When this condition occurs, the only possible method of maintaining the temperatures and humidities as required is by the physical addition of sensible heat to the air—in other words, reheating.

Assume that with a coil temperature of 50° we encounter a condition wherein it becomes necessary to remove just as much latent heat as sensible heat in order to maintain the temperature at 80° and the relative humidity at 50%. This means that the ratio between sensible to latent heat removed becomes 1.0.

Obviously we must supply air to the rooms at some condition where the difference in sensible heat between the air discharged and the air in the room is equal to the difference in latent heat between the air discharged and the air in the room. This means that the air discharged must lie somewhere along a straight line on the chart drawn in to represent this ratio of 1.0. Referring to Fig. 22, if the coil temperature is 50° (point 'B"), the dew point of the air discharged will be somewhat higher as indicated at point "D" (54°). Therefore, the dry bulb temperature of the air to be discharged must be raised from 60° at point "D", to 70° at point "E" if we are to remove equal quantities of sensible and latent heat. We must cool the air down to 60° in order to obtain a 54° dew point and the only possible method of raising the dry bulb temperature to 70° before discharging it to the room is by adding heat to the air. This is done by passing it through a heating coil after it has been cooled. At that time when the air is discharged to the room, it is capable of taking up equal quantities of sensible and latent heat and therefore maintaining the conditions as given. Therefore, the addition of reheat is the only means of maintaining a definite relative humidity as well as a definite dry bulb temperature under a load condition that will give a ratio between sensible and latent heat smaller than that determined by the lowest coil temperature.

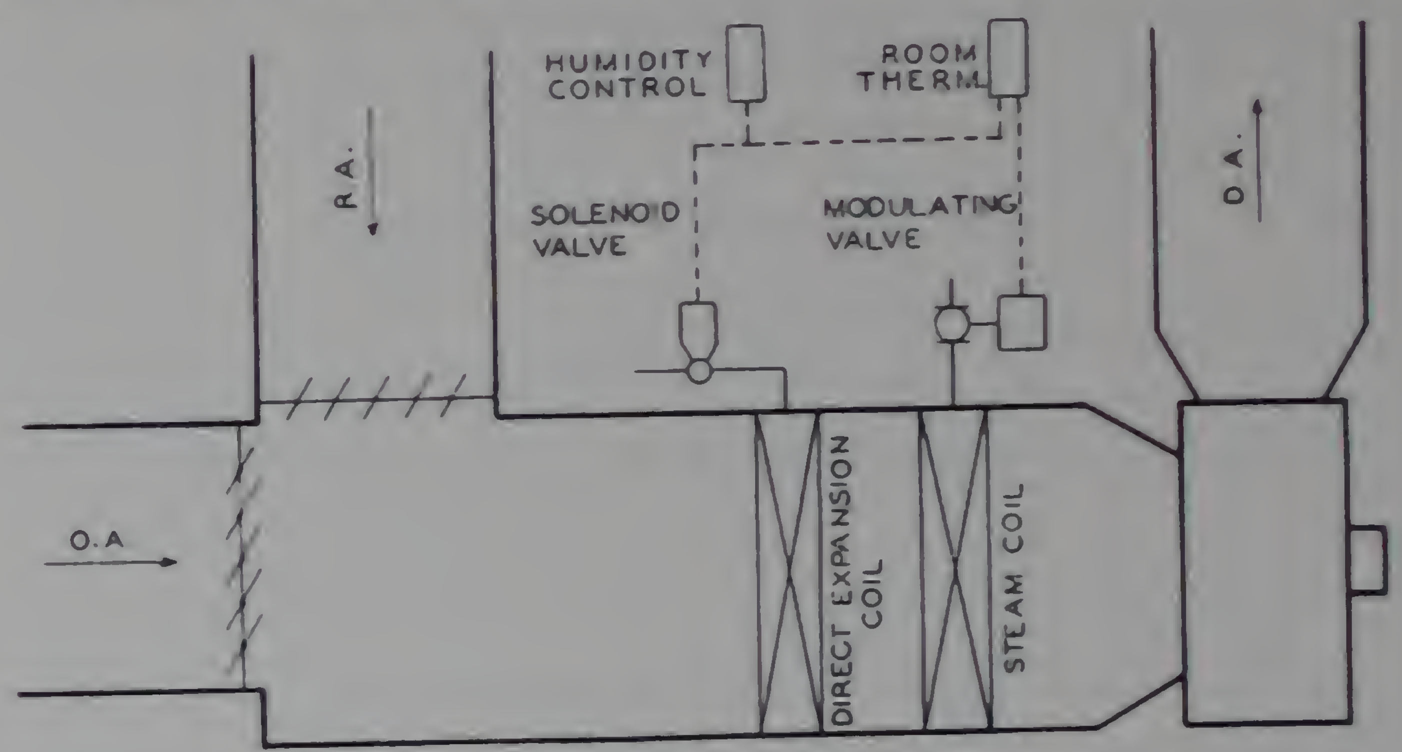


Figure 20

Fig. 20 illustrates a simple system for providing reheat. The thermostat serves two functions:

1. To operate the solenoid valve on the direct expansion coil to provide cooling in response to a temperature rise.
2. To modulate the steam valve to an open position to provide reheat when necessary.

The humidity control is also connected to the solenoid valve in such a manner that cooling will always be provided when relative humidity is high. Under conditions where the sensible load is light, this cooling for purposes of dehumidification would normally depress the dry bulb temperature below a comfortable level but the operation of the thermostat and steam valve as described under "2" above prevents this condition.

Sources of reheat other than steam are:

1. **Hot water coils.**
2. **Electric strip heaters.**
3. **Heat given off by the condensor in the refrigerating system**

The system as described under Fig. 20 will definitely provide means for maintaining the temperature at the setting of the thermostat and at the same time maintain the relative humidity at or below the setting of the humidity control. This conclusion is based on the assumption that the refrigeration equipment and steam coil are of sufficient size to handle the maximum load encountered.

Since this system does not provide a means of adding moisture to the air, it will be impossible to prevent the relative humidity from falling below the desired level under conditions wherein the primary moisture content of the air is extremely low. If the direct expansion coil is being operated under command of the thermostat alone, it is obvious that a certain amount of moisture will be removed from the air even though the humidity may be at the desired point. This general arrangement would, of course, be satisfactory on comfort conditioning applications but for certain forms of laboratory and industrial installations, a separate means of humidification would be necessary to prevent the relative humidity from occasionally dropping below the specified value.

Some control over relative humidity may be obtained on this system by adding a water spray in the air stream before the air enters the cooling coil. This spray would be operated in the event of a drop in relative humidity. The water spray performs some sensible cooling of the air and raises its humidity before it enters the cooling coil. Thus the over-all S/L ratio of the system is increased. The control, which may be obtained by this method is limited by the ability of the air entering the cooling coil to absorb moisture.

CONTROL OF CENTRAL FAN COOLING SYSTEMS

Any of the cooling cycle air-conditioning systems described can be arranged in such a manner that the function of reheat is provided. In providing a system of reheat the following sequence of operation should be provided:

1. **Modulating control of reheat medium to provide heat on a drop in temperature.**
2. **Modulating or two-position control of the cooling medium to provide additional cooling on a rise in temperature.**
3. **Final control of the cooling medium from a relative humidity controller.**

When operating refrigerating coils from a relative humidity controller or a reheat system, it is usually preferable to arrange the equipment in such a manner that the lowest possible coil temperature will be provided

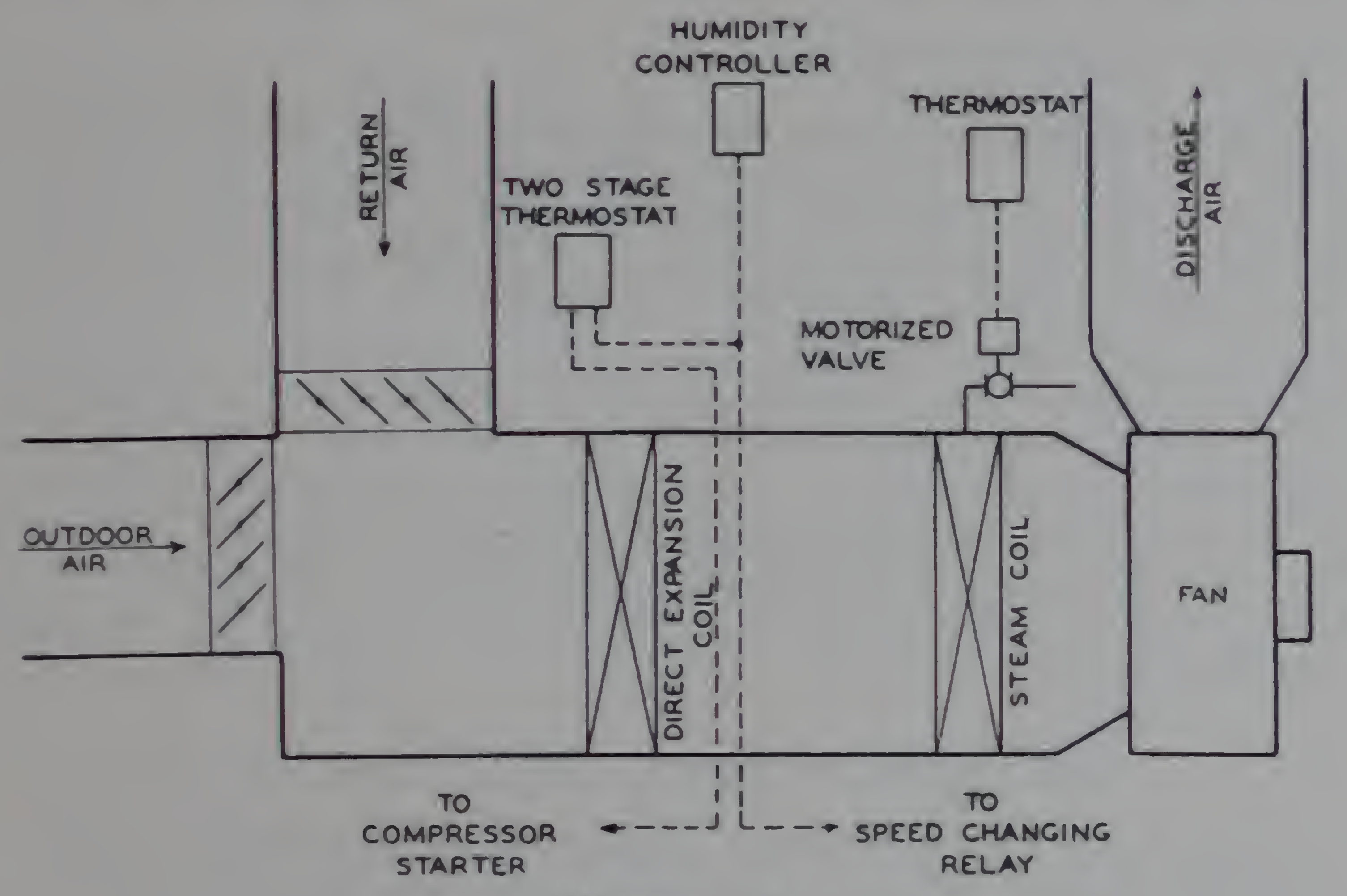


Figure 21

when there is a demand for dehumidification and where reheat will be necessary. The reason for this lies in the fact that the greatest proportion of latent heat is removed from the air at this low coil temperature condition. Since the proportion of latent to sensible heat removed increases on a decrease in coil temperature, less total reheat will be required when the system is operated under these conditions.

Fig. 21 illustrates a method of reheat control applied to an installation on which two steps of refrigeration are available. On a rising temperature the two cooling stages are brought on in sequence. When the relative humidity is high, the compressor is operated at maximum capacity under the control of the humidity sensitive element.

Should the room temperature drop as a result of this demand for dehumidification, the thermostat will operate the steam valve to provide the necessary degree of reheat. This system is similar to that shown in Fig. 20.

This system should maintain uniform temperature and humidity conditions as long as the load is strictly one of cooling and providing the system is designed in such a manner that the amount of air handled and the coil temperatures maintained will bear a proper relation to the maximum sensible and latent loads as well as the extreme ratios between these loads.

CONTROL OF OUTSIDE AIR DAMPERS

Ventilation is one of the important functions of the air-conditioning system and on the usual installation it is required that a certain minimum amount of outside air be taken into the system at all times to provide this ventilation.

However, it can be seen that under some conditions it is much more economical to take the outside air and condition it rather than to recirculate air from the spaces being conditioned.

The control of the outside air dampers therefore should bear a relation to the outside air temperature and when the outside air temperature is at a lower temperature than the temperature in the room, the system should take 100 per cent outside air. The economies resulting from this type of control are obvious.

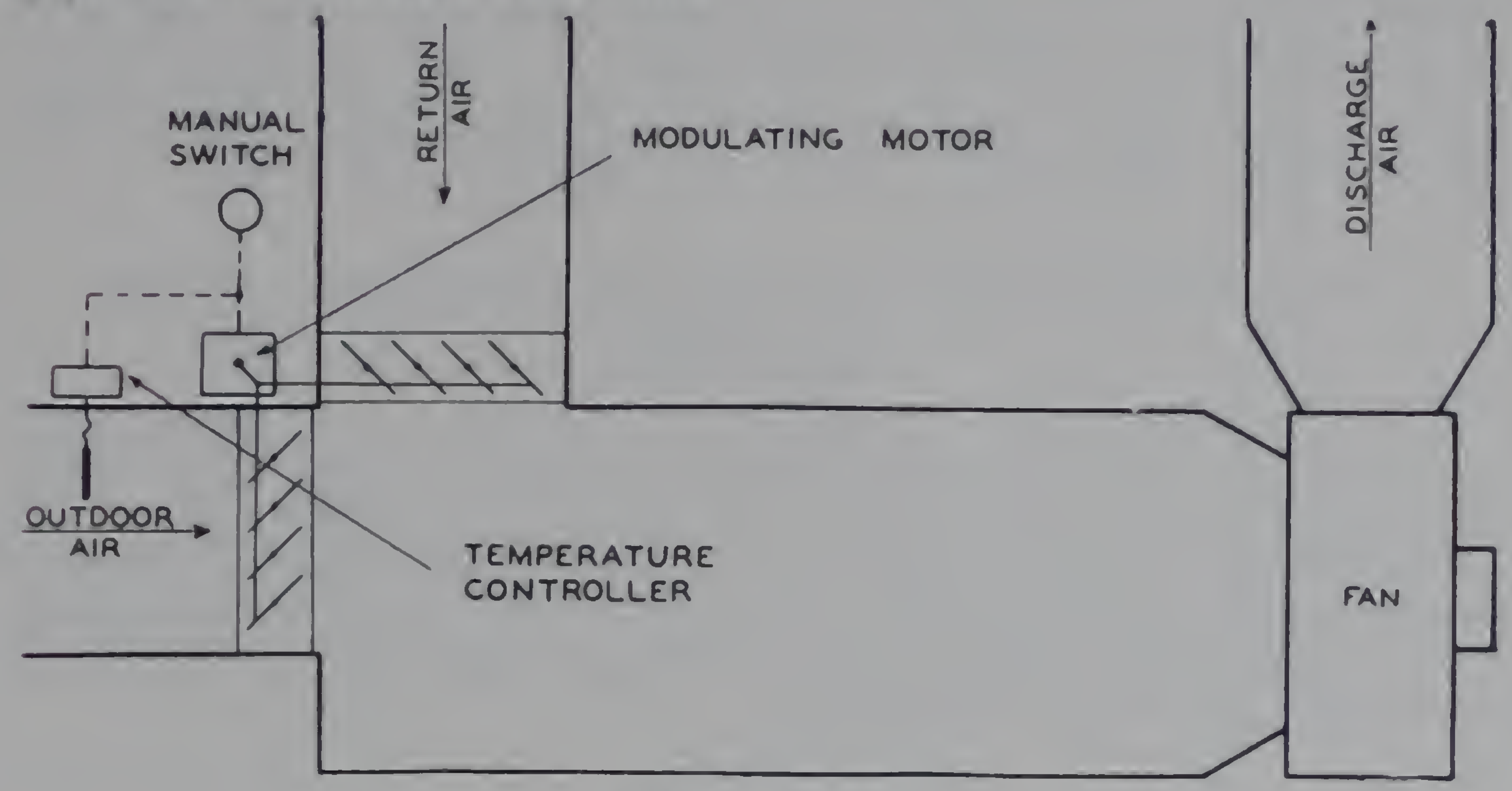


Figure 22

Generally the control of the outside air damper is as shown in Fig. 22. A modulating type damper motor is used to position the return air and outside air dampers. This is controlled by a manual rheostat that permits setting any minimum required on this motor. In the circuit is a remote bulb controller measuring the temperature of the outside air. This is set at the control point of the inside thermostat. Then, whenever the outside air reaches a temperature below the inside control point, the dampers will be caused to open up to the 100 per cent outside air position regardless of the position of the manual positioner. The manual positioner can be located at any convenient point and it is generally the practice in theatres and auditoriums to have the switch located in the manager's office or at some point where the minimum volume of outside air can be adjusted to the number of occupants.

It is obvious that the additional control required for outside air control is well justified in terms of the savings effected by using the cool outside air during times when conditions are favorable. Very frequently the outside temperature may be very high during the day but at night will cool off very sharply. If a building has been heated up and has a fairly high internal heat load, the temperature can be much higher inside than it is outside and under that condition this type of system will take all outside air.

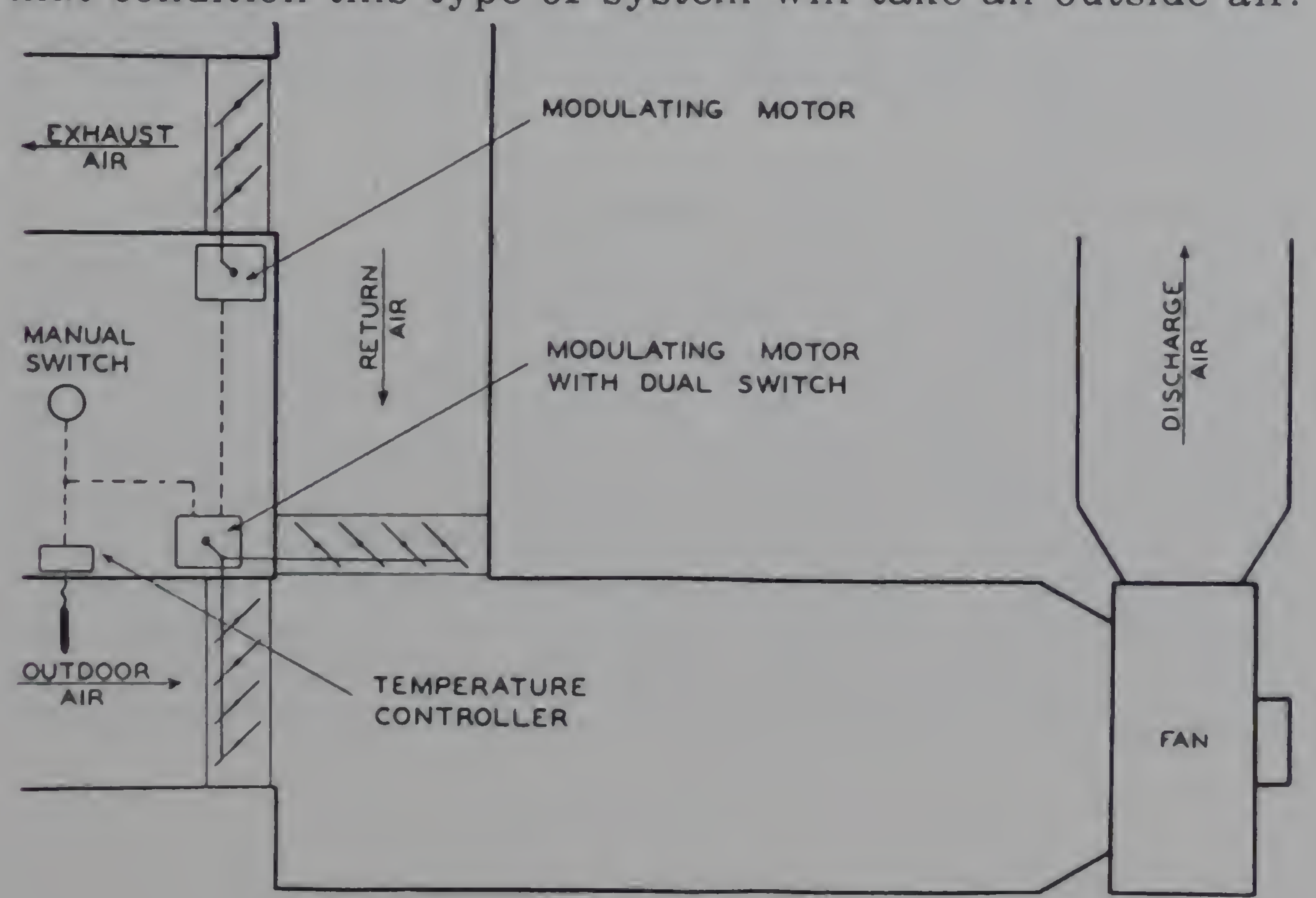


Figure 23

In some types of systems where the building is extremely tight and there is very little leakage, closing off the recirculated air damper and opening the outside air damper may cause a pressure to be built up and reduce the air

CONTROL OF CENTRAL FAN COOLING SYSTEMS

volume handled by the fan. On an installation of this type where there is not sufficient leakage, it is necessary to control an exhaust damper simultaneously with the control of the return air and outside air damper. This type of control is shown in Fig. 23 and will consist simply of a second motor operating an exhaust damper which is positioned by a dual arrangement with the first motor on the outside and return air dampers so that all three dampers move together, the exhaust damper and the outside air damper opening as the return air damper closes.

COMPENSATED DRY BULB TEMPERATURE CONTROL

In all of the summer cooling systems that have been discussed up to this point, temperature control has been obtained through the use of a room or return air type thermostat. Actually the control of dry bulb temperature at a fixed point during the cooling cycle does not provide optimum comfort conditions.

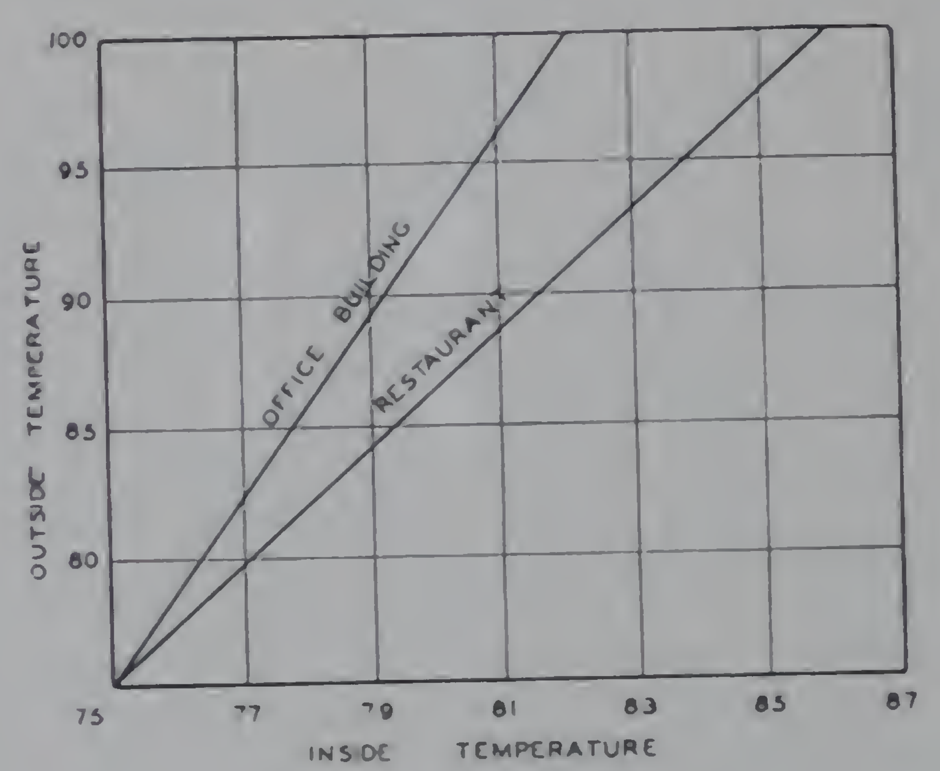


Figure 24

Tests conducted in conjunction with the A. S. H. & V. E. laboratories on 275 office workers in the air conditioned offices of the Minneapolis-Honeywell Regulator Company have demonstrated that the comfortable level of inside dry bulb temperatures will vary with outside temperature conditions. As the outside temperature increases the inside control point should also be raised.

Fig. 24 illustrates a recommended relationship between inside and outside temperatures during the cooling season. Actually this relationship will vary for different types of installations.

Factors Effecting Inside Temperature

The duration or period of occupancy will be the determining factor in establishing the final relationship between inside and outside temperatures for any specific installation. In an office building where there is a continuous occupancy during the day the rise in inside control point per degree increase in outside temperature would be less than in the case of a restaurant or theatre where the occupancy is of shorter duration. This can be attributed to the fact that ultimate exposure to a low and high temperature condition within a short period of time will cause severe shock to the human nervous and circulatory system. The degree of shock is far less pronounced as the frequency of alternation between the two exposures is decreased.

Tests have further shown that for short-time occupancy the inside-outside temperature relationship is effected to some extent by climatic conditions and geographical location.

It becomes necessary therefore to provide control of comfort air-conditioning not from a fixed setting thermostat, but rather from one which will vary the inside temperature in accordance with outside conditions. This requires a compensated system of control equipped with means for readily adjusting the relationship between inside temperature control point and outside temperature in order that it may be uniformly adapted to various types of installations.

Method of Compensation

To accomplish this function an outside thermostat is provided and interconnected with the indoor controller in such a manner that the inside control point will be electrically or pneumatically reset in response to variations in outside conditions. Thus, referring to Fig. 27, in the case of an office building, it would be possible to change the inside control point between 75° and 82° on a variation in outside temperature between 75° and 100° limits. Likewise, in the case of a restaurant, the inside temperature could be automatically readjusted between 75° and 86° limits while the outside temperature changed from 75° to 100°. For further details refer to pages 23 through 26, Section III.

SUMMER-WINTER CHANGEOVER

Where air-conditioning equipment is installed to provide the combined functions of winter heating and summer cooling, it is desirable to exercise particular care in the selection of automatic control equipment.

While it is possible to operate such systems in two phases, one to cover the heating cycle and the other to cover the cooling cycle, it is both desirable and economical to arrange the control system in such a manner that automatic changeover will be obtained.

There are, during the late spring and early fall periods, occasions when the demand made upon the conditioning system may change from day to day from heating to cooling operation. Unless special provision is made in the design of automatic controls, it will be necessary to:

1. **Undertake the responsibility for manual changeover.**
2. **Suffer loss of efficiency and comfort.**

During the mild seasons it is often necessary that heat be supplied during the morning and evening hours while temperature and humidity conditions are such during the day that cooling operation is desirable. Where the system is of such design that it is a burdensome task to change it in accordance with these fluctuations, the satisfaction of the user cannot be as complete as in the case where these changes are accomplished without manual attention on his part. If both the air-conditioning and control systems are designed with automatic changeover in mind, the addition of this feature involves only slight additional expense. This expense may be considered self-liquidating in view of the fact that the maximum profits are from the year around conditioning system under all load conditions.

CONTROL OF
UNIT HEATERS
UNIT COOLERS
AND
UNIT VENTILATORS

SECTION V

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Unit Heater Control

Unit Heaters find wide application for the heating of commercial and industrial types of buildings. They provide a very flexible heating system which can be quite easily re-arranged to meet changes in heating requirements resulting from re-arrangements of floor space or the addition or removal of partitions.

Careful consideration should be given to provide adequate control for any unit heater installation. Both the comfort conditions in the space and also economy of operation depend upon the proper choice of control.

The flexibility of unit heater heating systems to a large degree is the result of the control system. Individual bays on a particular floor can be controlled as a single zone so that during certain periods of the day when the bay is not in use, the temperature in that particular area can be lowered in order to save steam. Likewise, certain areas of the building can be heated for overtime or night shifts without making it necessary to keep the entire floor or building at the normal daytime temperature.

There are two types of control systems which can be used for unit heaters. Modulating control has several advantages which recommend this type of system over the conventional "On-Off" control. With the Modulating system, the fans are allowed to operate continuously and the steam supply to the unit is throttled. In this way, a constant discharge temperature for a given condition is maintained, and unpleasant hot blasts of air are eliminated. Also, with continuous circulation, there is little tendency for the air to stratify as it does with "On-Off" control systems whenever the fan stops.

Modulating control can be obtained with either pneumatic or electrically operated equipment. In many cases, the pneumatic system will prove less expensive, particularly if an air supply is already available.

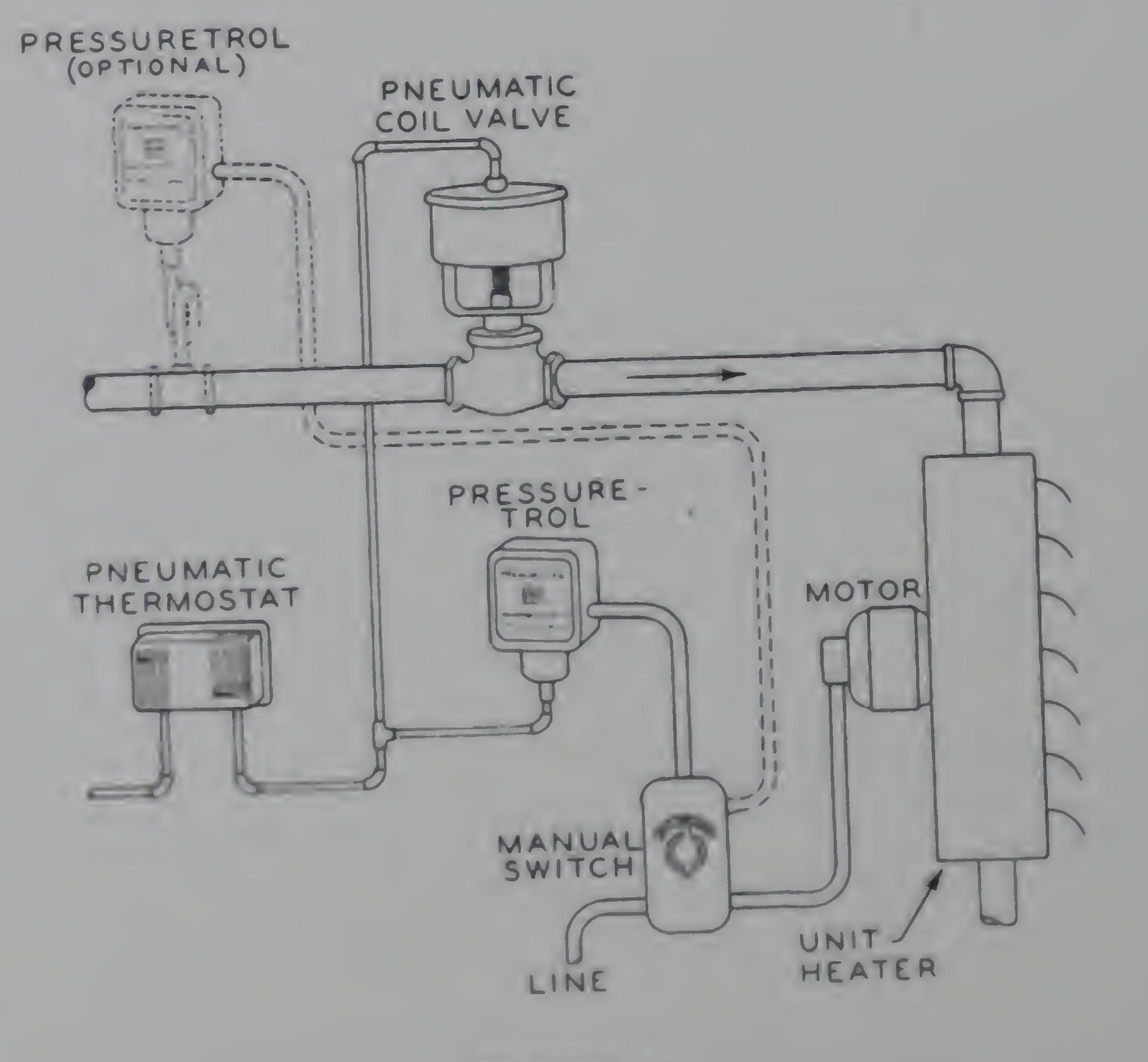


Figure 1

MODULATING PNEUMATIC SYSTEM

The basic pneumatic modulating control system illustrated in Figure 1 consists of a graduate acting thermostat, a steam valve, a pressure control switch, and usually a manual switch for controlling the fan operation. The graduate thermostat reacts to the space temperature and positions the throttling steam valve accordingly. A Pressuretrol is connected into the valve branch line so that when the thermostat has throttled the valve to some predetermined point, the pressure control switch will stop the fan motor. In this way, the possibility of blowing too cool air, when the steam valve closes, is eliminated. The adjustment of this Pressuretrol depends, of course, upon the characteristics of the particular unit heater on which it is installed.

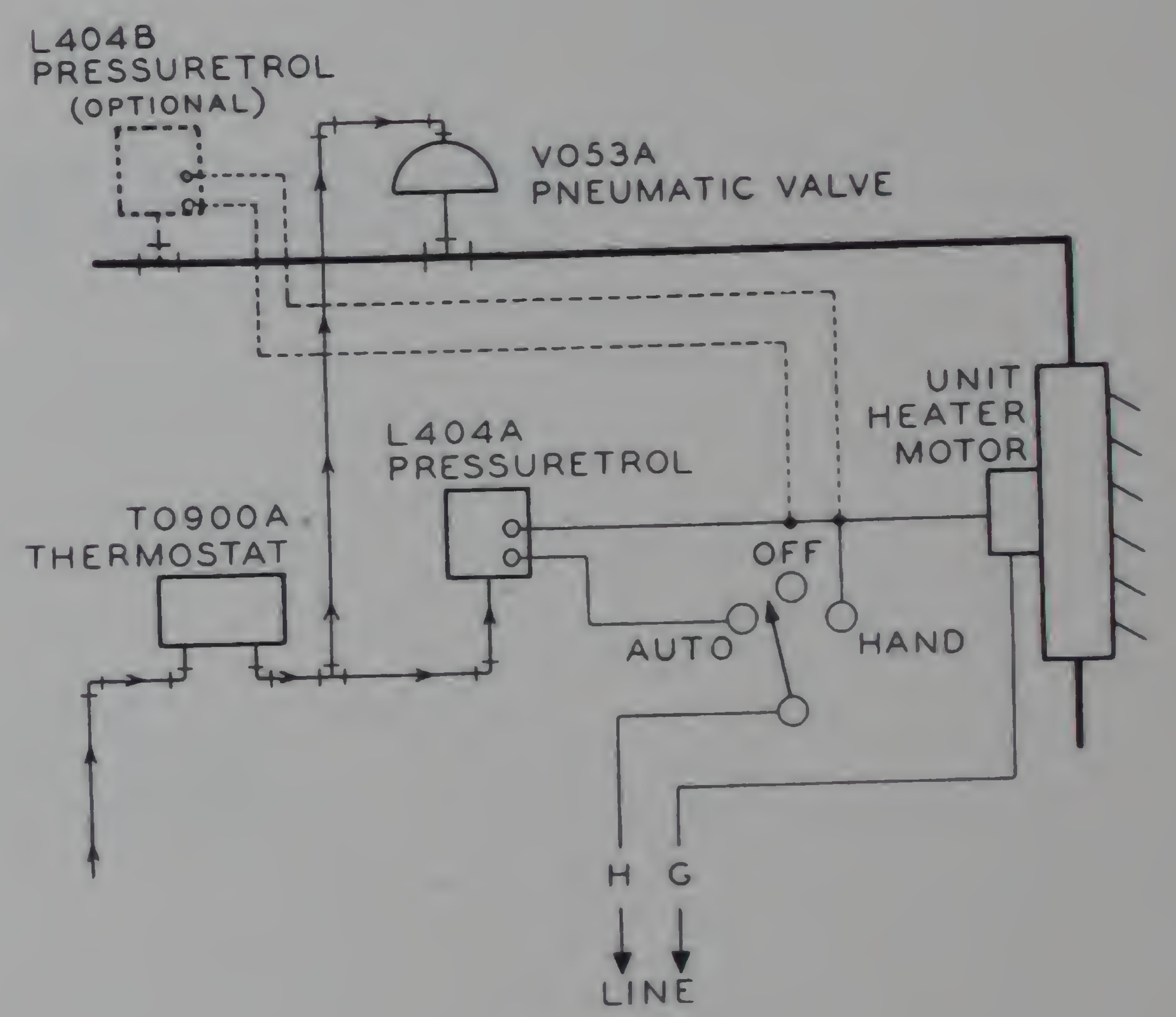


Figure 2

It is sometimes advisable to include a second pressure control mounted in the steam main on the up-stream side of the steam valve. This pressure control will eliminate the possibility of running the unit and discharging air at those times when there is no steam available.

The piping and electric wiring of this system is illustrated in Fig. 2

Lowered Night Temperature

There are several methods for providing lowered night temperature with pneumatic modulating control systems. The choice of a particular night shutdown system will depend upon the requirements of the particular installation.

UNIT HEATER CONTROL

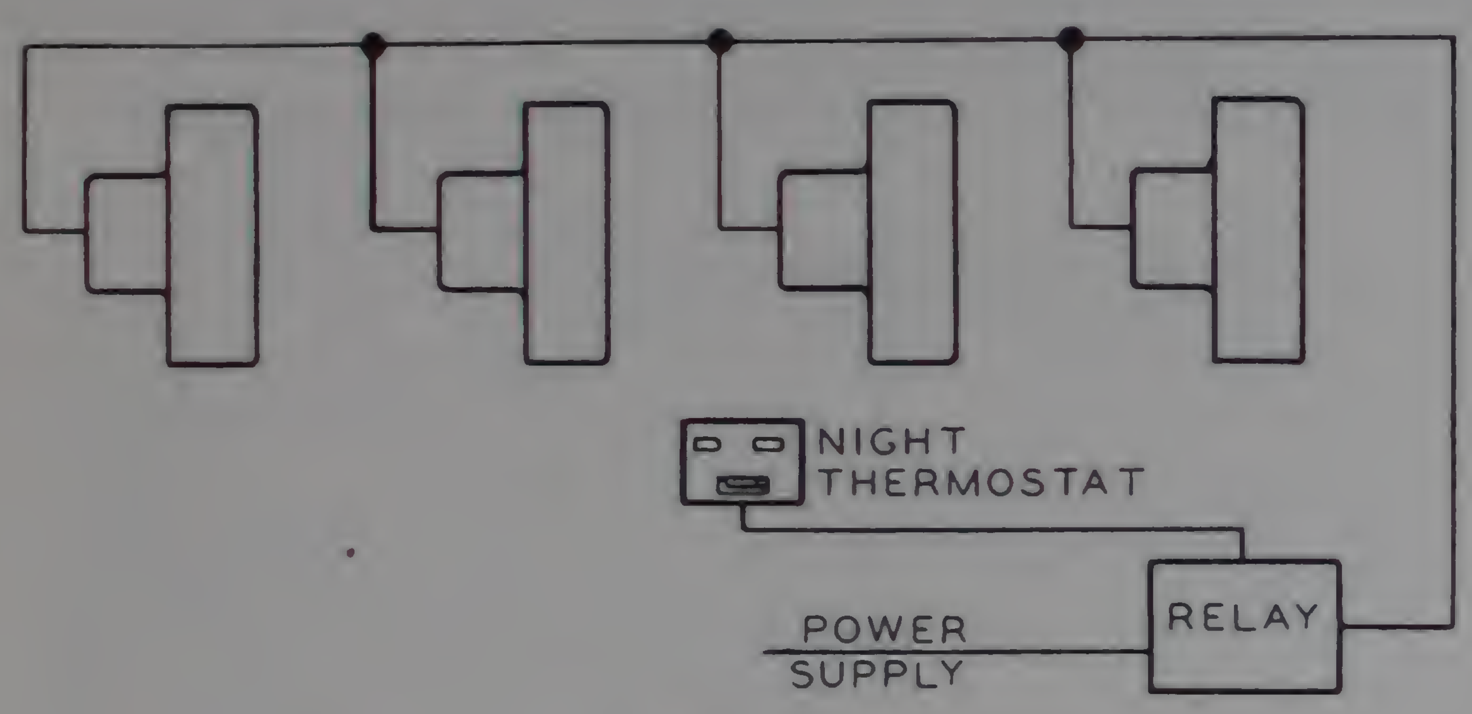


Figure 3

If the power supply for all of the unit heaters can be run through one centrally located relay, a simple method for providing lowered night temperature is to operate such a relay from a two-position electric thermostat as shown in Fig. 3. Either an automatic time switch or a manual switch is included to change over the control of the unit heater motors to the night thermostat.

During the night operation, the fans will remain off until the temperature has dropped to the setting of the night thermostat. At that time, all of the fans will start and will remain in operation until the night thermostat is satisfied. All of the normal day thermostats will be calling for full capacity because, of course, the night temperature will already have dropped below their normal day setting. At some predetermined time in the morning, the control of the units can be returned to the regular day thermostats, with the proper allowance of time for a morning pick-up period.

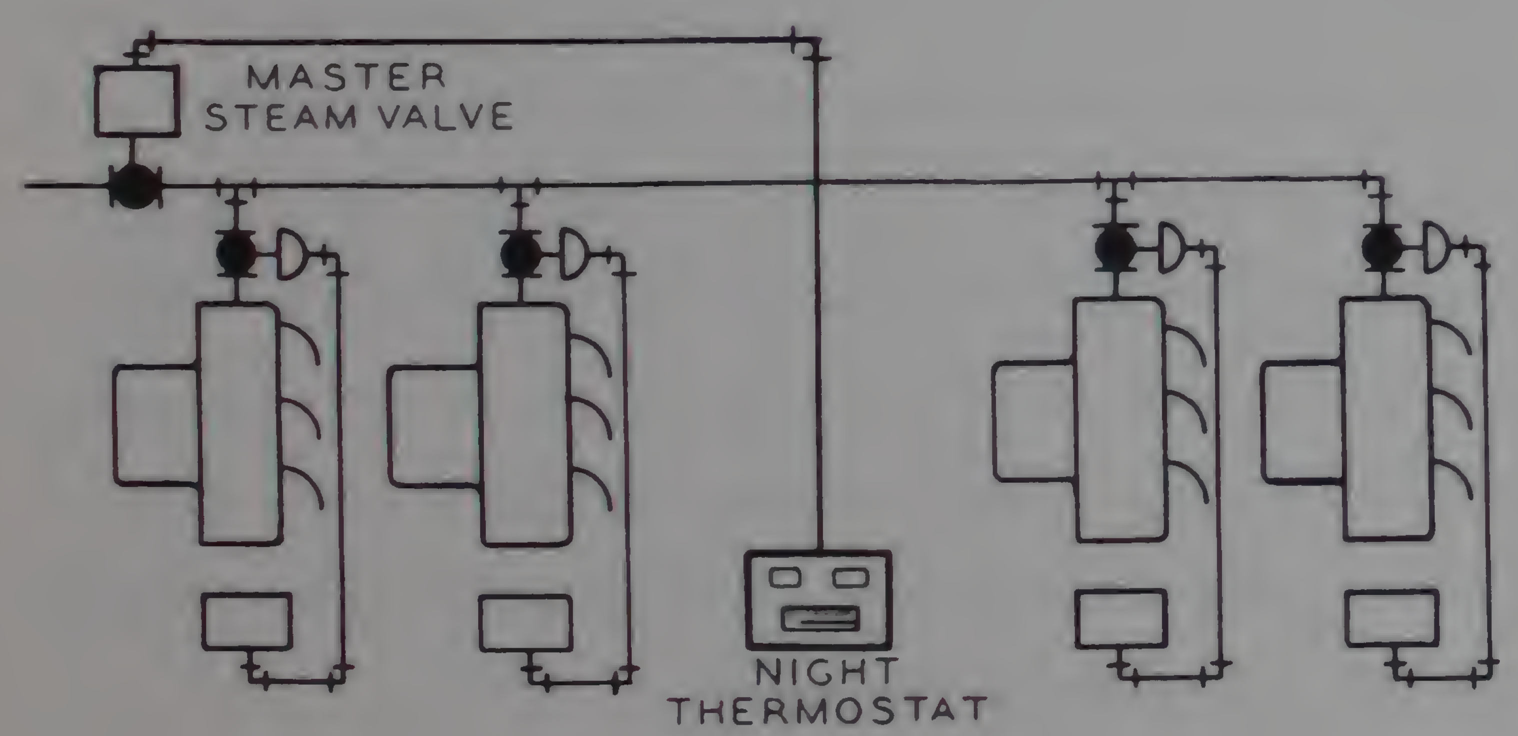


Figure 4

Another similar system for night operation, shown in Figure 4, makes use of a large steam valve in the steam main serving a particular zone or wing. In this case, the night thermostat controls the operation of the master valve so that during the night, the steam supply to the zone will be under the command of the master night thermostat. Whenever steam is available at the various units, their own control systems will take over and operate the units at their maximum capacity until the supply of steam is interrupted by the night controls.

In either of the systems described above, an automatic clock-type thermostat can be used for controlling either the relay or the valve.

On those systems where there is no danger of night temperature dropping too low, the night low limit thermostat can be eliminated and the relay or valve operated directly by a time switch. With this arrangement no heat would be available during the night.

Another method for reducing temperatures during the night on pneumatic systems makes use of a two-temperature thermostat known as a Da-Nite ★ Grad-U-Stat. Through a simple changeover in the main line air pressure, such a system can be easily changed from night to day operation, or vice versa, from a central location. This changeover can be made, either manually or by means of an automatic Timeswitch.

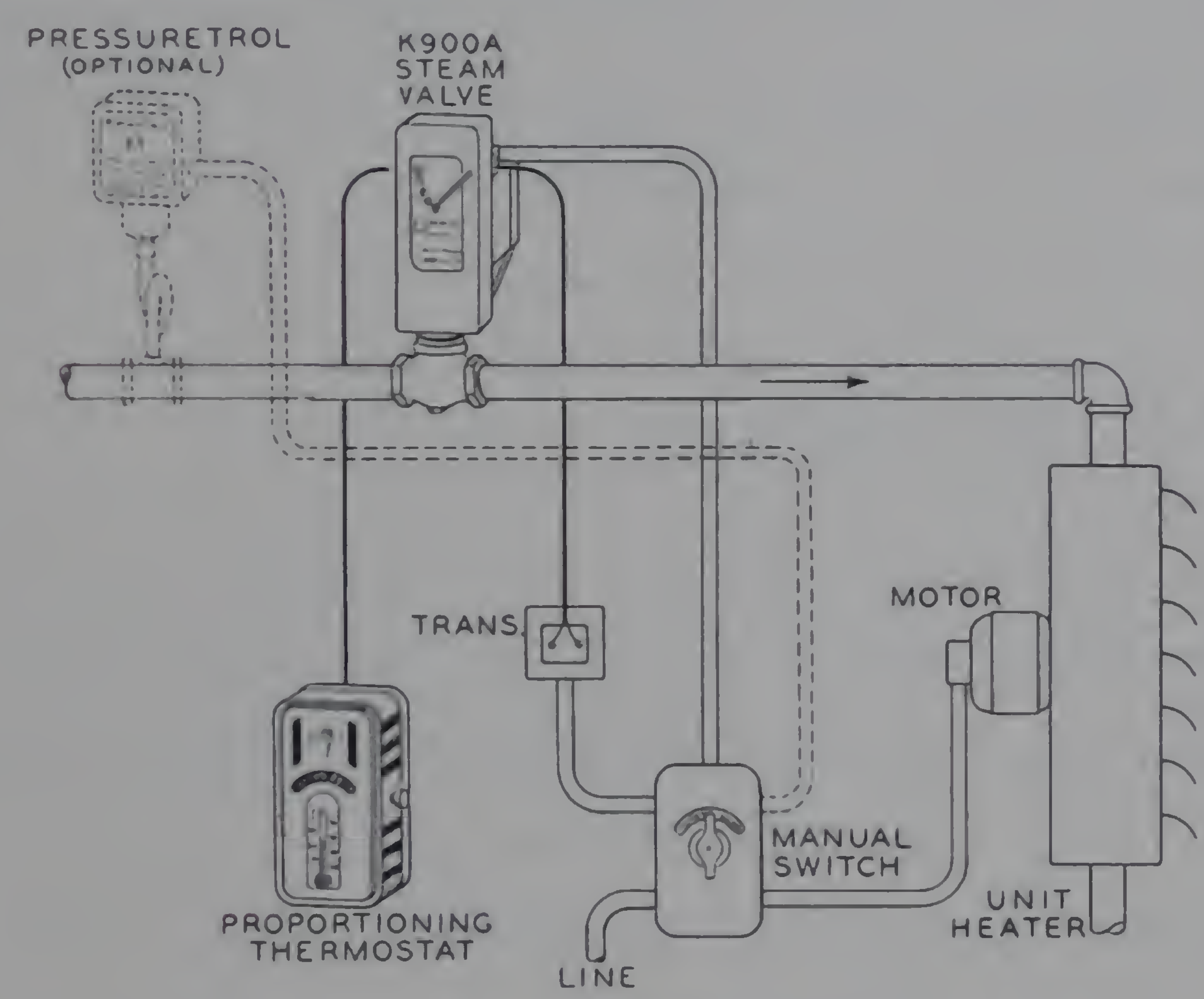


Figure 5

ELECTRIC MODULATING SYSTEM

The electric modulating systems illustrated in Figures 5 and 6, provide exactly the same sequence as the pneumatic systems already described. The proportioning thermostat controls the operation of a modulating steam valve which is equipped with an auxiliary switch for controlling the unit heater motor. This auxiliary switch serves the same purpose as the Pressuretrol in a pneumatic system.

When the thermostat has throttled the steam valve to a point where too cool air is being discharged, the auxiliary switch interrupts the operation of the unit heater motor. A manual switch is also included with the electrical system.

UNIT HEATER CONTROL

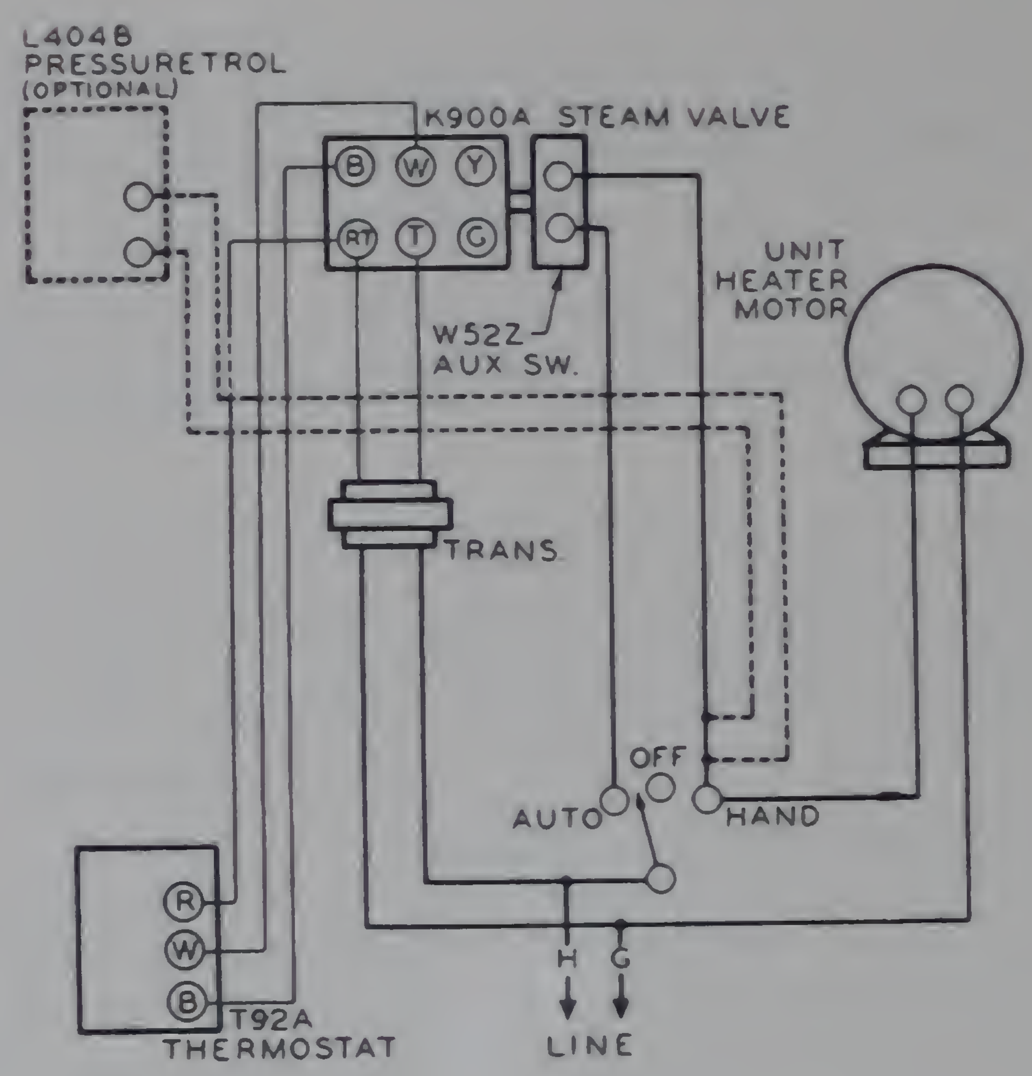


Figure 6

The optional Pressuretrol installed in the steam line on the upstream side of the valve may also be used in the electric system. This Pressuretrol is capable of interrupting the operation of the unit heater motor whenever the steam pressure in the main drops.

Lowered Night Temperature

Lowered night temperatures can be maintained in the space through the use of a separate night thermostat and a relay controlling the power to all the unit heater motors. This system is identical to the one described above for use with pneumatic systems. The thermostat may be either a plain pattern thermostat with a manual switch, or it can be an automatic clock type thermostat.

An alternate system would make use of a master steam valve, controlling the supply to all the unit heaters in one particular area. This steam valve would be controlled by a master thermostat which might be either a plain pattern or an automatic clock type thermostat. This arrangement is exactly the same as the one described for the pneumatic system above..

If there is no possibility of the space temperatures dropping to dangerous levels during the night, the low limit thermostat can be eliminated and an automatic time switch used for controlling the master valve or relay.

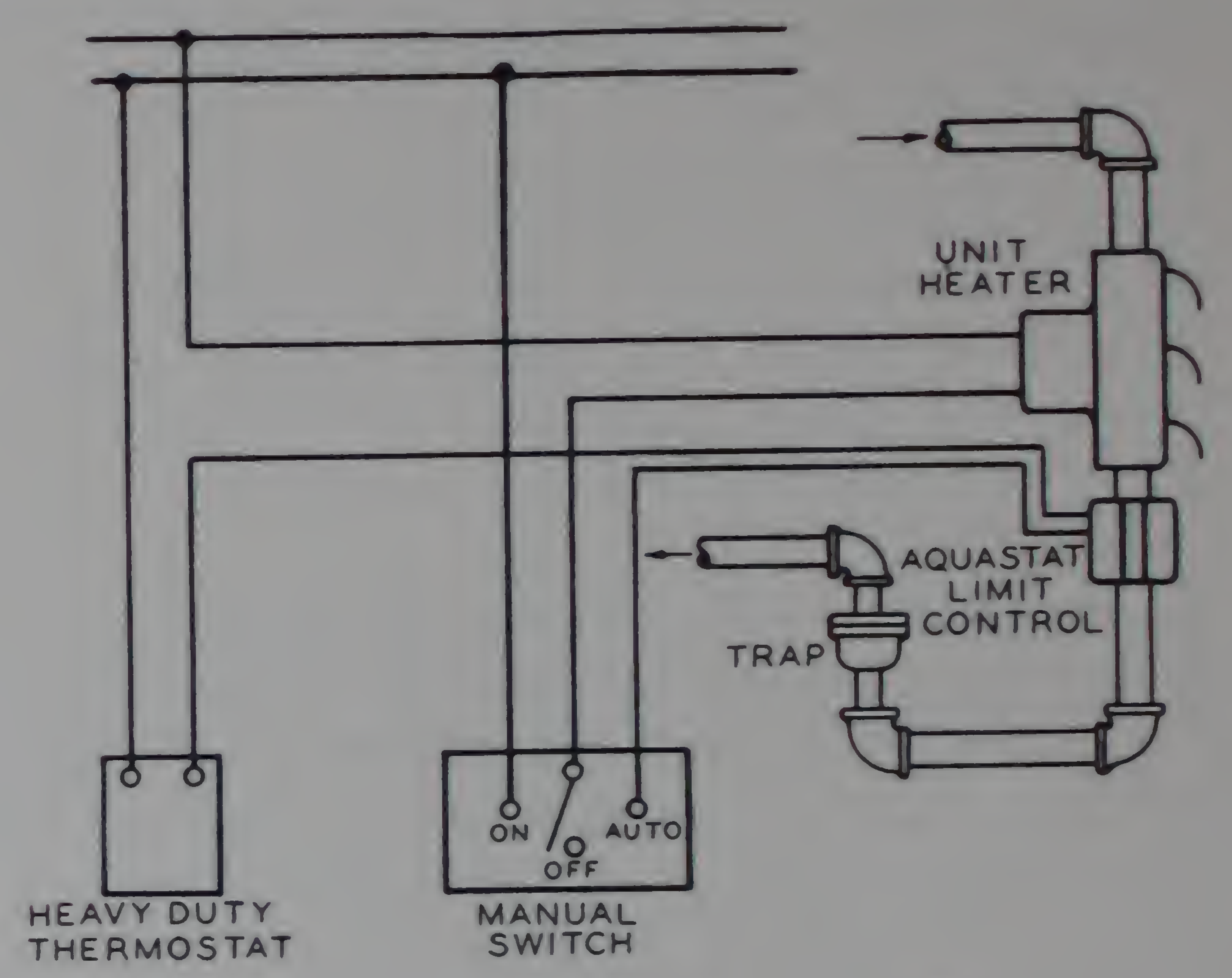


Figure 7

TWO-POSITION CONTROL SYSTEMS

The most common control system used in unit heater work consists of a heavy-duty electric thermostat, controlling the operation of the unit fan together with a low limit control to prevent the operation of the fan until the coil is filled with steam. This system is illustrated in Figure 7.

Some type of switch is always used to control the fan motor. A popular type is a three-position switch which can run the fan continuously, shut the fan off positively, or place the thermostat in control of the fan. The application of this system is always limited by the electrical rating of the thermostat. For very large units or for three-phase current supply, starting relays will have to be used. In this case the thermostat will merely act as a pilot control for the pull-in coil of the starter.

A similar control system makes use of a sensitive Series 10 thermostat and a Series 10 relay. This system is slightly more expensive than the system described above; however, it is capable of maintaining the temperature between closer limits. Also, this system adapts itself very readily to the use of clock type thermostats for lowered night temperatures. The system is illustrated in Figure 8.

UNIT HEATER CONTROL

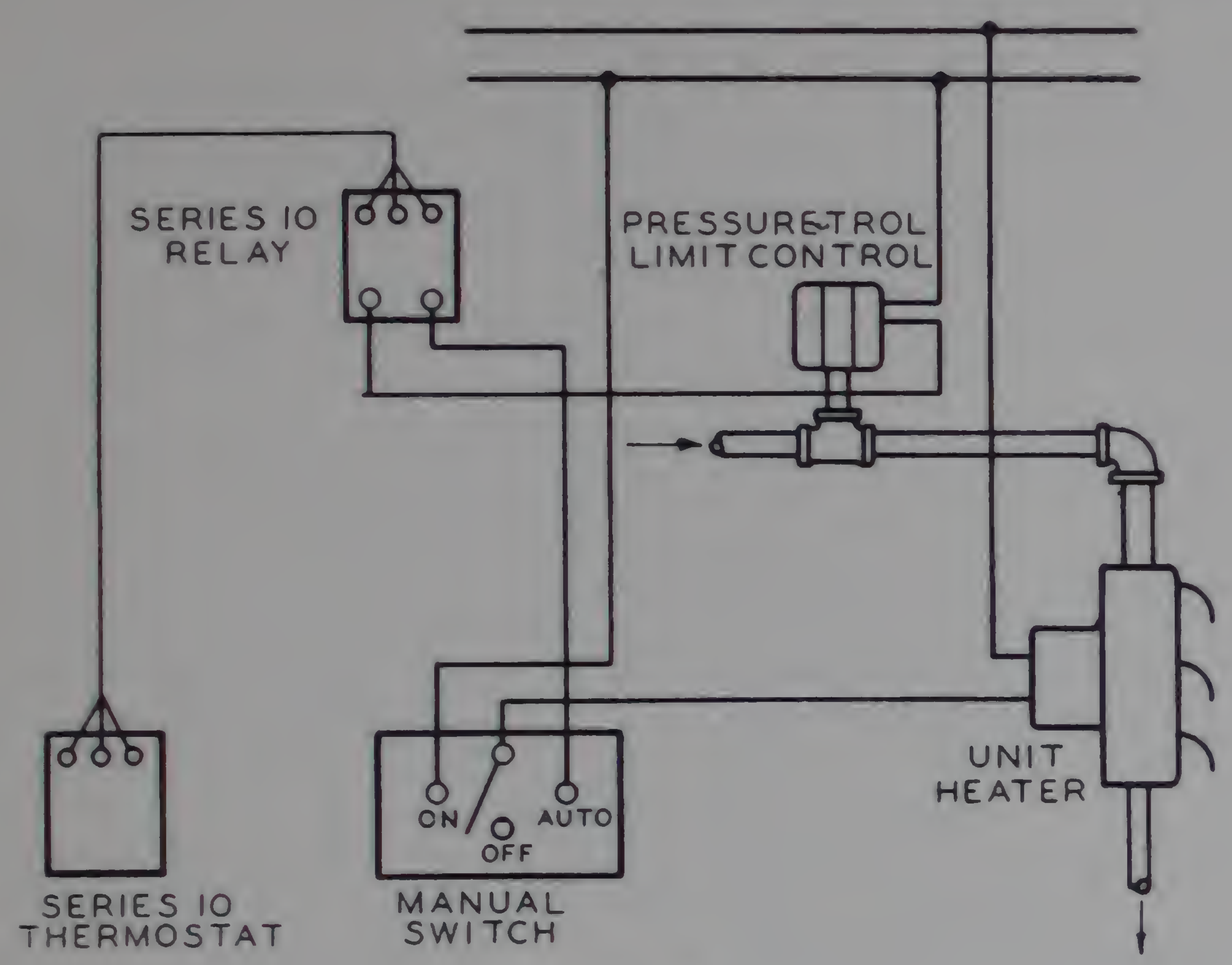


Figure 8

Low Limit Control

On any two-position control system where the fan operation is controlled from a thermostat, some type of low limit control must be included to prevent operation of the unit when no steam is present in the coil. If the unit is operated with no steam in the coil a very uncomfortable blast of cold air may be delivered.

There are two types of low limit controls which are commonly used. A Surface Aquastat can be strapped on the return line between the unit and the trap, and can be wired into the fan circuit so that the Aquastat will complete a circuit on a temperature rise as indicated by the presence of steam in the return line on the upstream side of the trap. An Aquastat is oftentimes strapped to the face of the unit heater core itself to indicate the presence of steam.

Pressuretrols in the steam supply line are also used very extensively in a similar manner. The Pressuretrols are the type that will complete a circuit on a rise in pressure, thereby allowing the thermostat to complete the fan circuit only when steam is present.

Either the Aquastat or the Pressuretrol type of limit control can be used with either of the control systems outlined above.

Lowered Night Temperature

Lowered night temperature for a particular zone can be accomplished either by means of a master valve, controlling the steam supply to all the units or through the use of a relay which supplies all the power for the various unit heater motors. This relay or valve can be controlled from a Timeswitch. If there is danger of the temperature in the space dropping to too low a level during the night a night low limit thermostat can also be included which will operate the unit heaters whenever the temperature in the space drops below some pre-determined level. Clock type thermostats are also sometimes employed for controlling the master valve or master relay.

UNIT COOLER CONTROL

Unit coolers are now available in sizes up to a maximum of 15 to 25 H.P. These units are complete package units requiring only connections to electrical, water, and sewer services. Sometimes they are connected to duct systems although many of them are installed to discharge directly in the cooled space. In view of the fact that unit coolers are installed to decrease the temperature of the space during summer months to increase comfort conditions, the matter of proper control should be given very careful consideration.

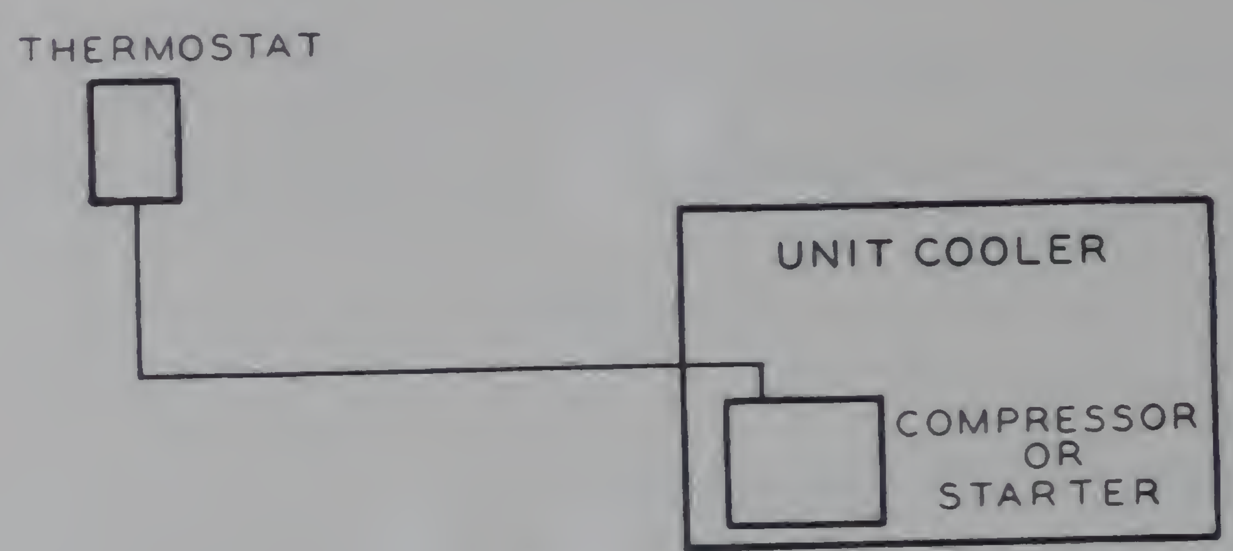


Figure 1

Figure 1 illustrates the simplest type of temperature regulation. A reverse-acting or cooling type of thermostat operates the compressor in accordance with the cooling demand. The fan is normally run continuously in order to provide constant circulation of air.

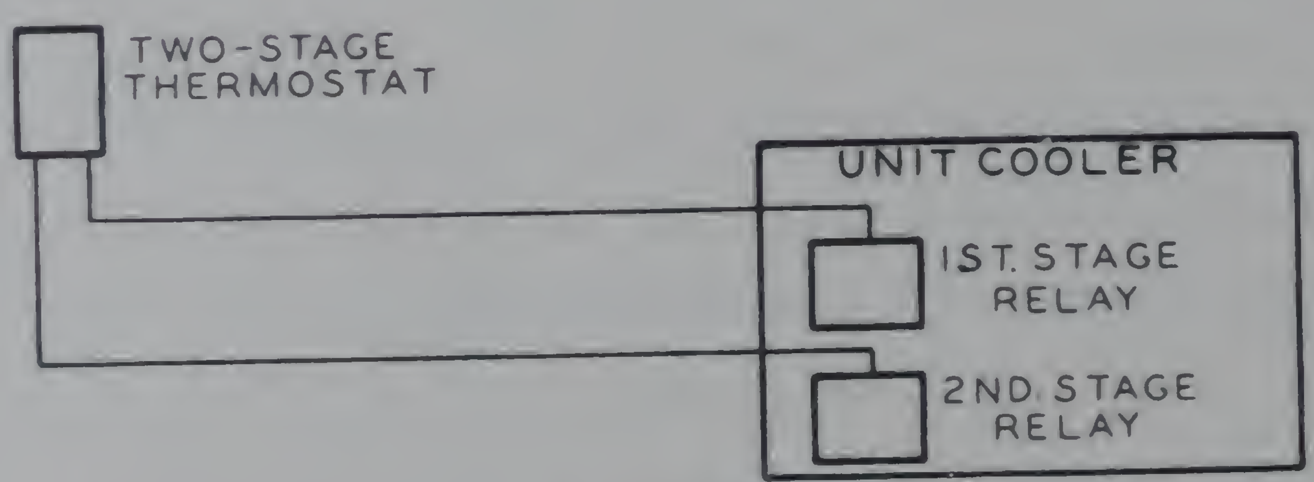


Figure 2

The control system shown in Figure 2 is used on units which include two stages of cooling capacity. On the initial rise in temperature, the two-stage thermostat starts the unit on the first stage at reduced capacity. As the temperature continues to rise, the thermostat makes a second contact, which brings in the second stage of refrigeration. The fan is usually operated continuously.

This system provides for long operation on the first stage during light load conditions, which is very advantageous on many installations because it eliminates cyclical variations in temperature and humidity. If the entire unit were controlled as a single stage it would mean that during light loads the unit would run for only short periods of time at full capacity with resultant fluctuation in humidity and temperature.

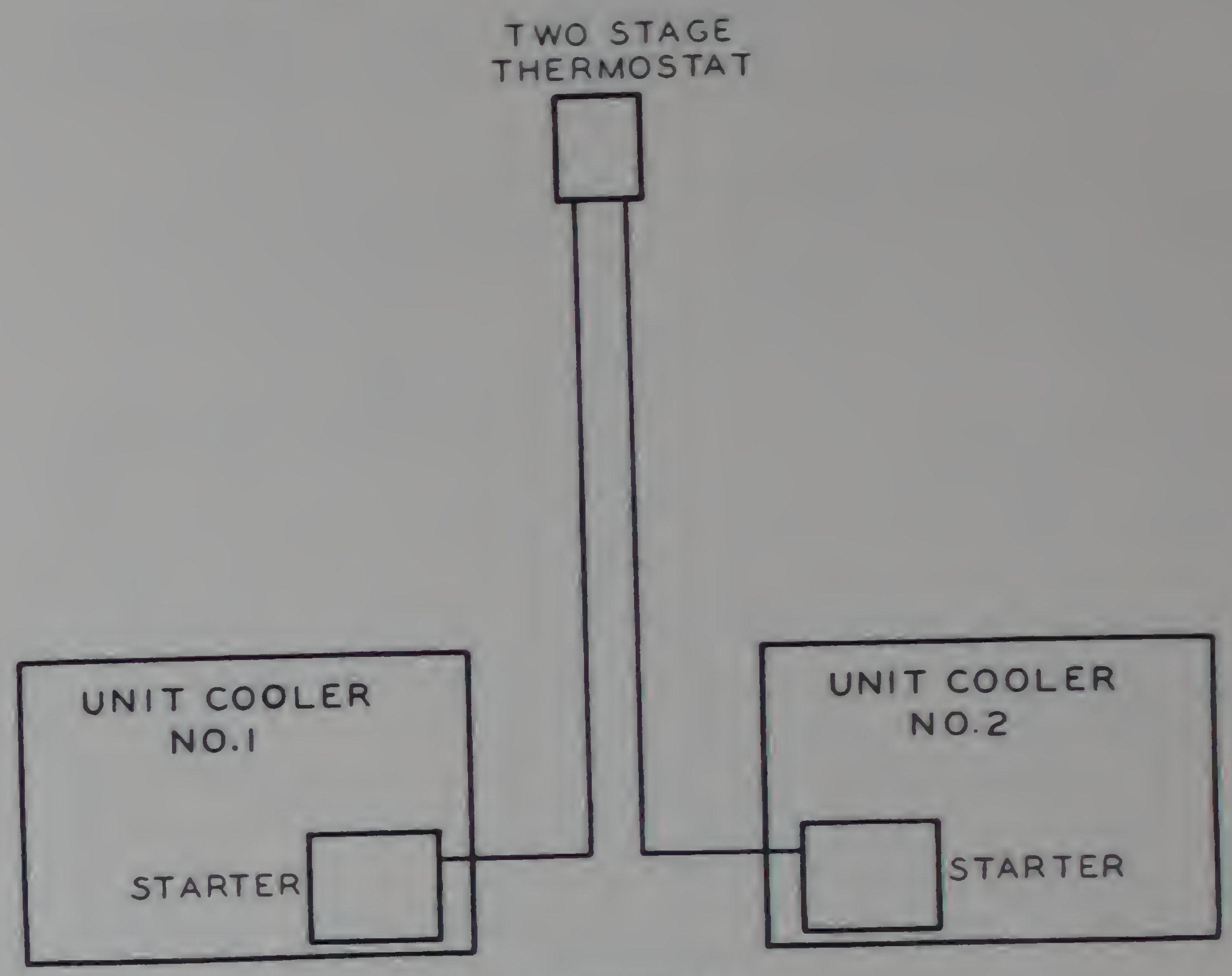


Figure 3

Figure 3 shows a system very similar to the one described above, except that two separate units are operated from the two-stage thermostat. Operating the two units as separate stages provides the same advantages as those outlined for the two-stage operation of a single unit.

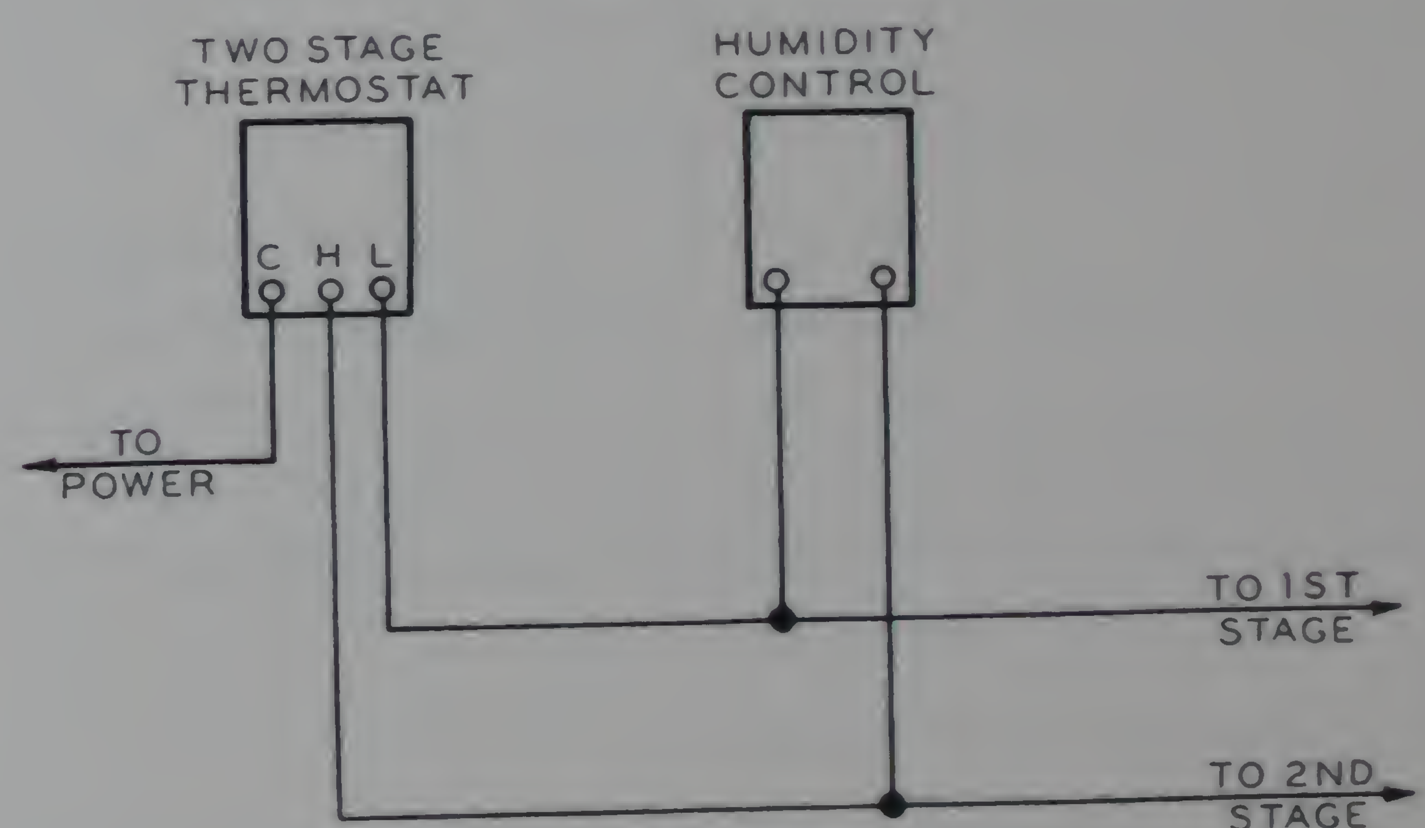


Figure 4

The Schematic wiring shown in Figure 4 is used with either type of two-stage system to provide for the control of humidity.

The humidity control is connected into the control circuit so that if the thermostat is calling for cooling on the first stage, as it would in mild weather, the humidity control will be capable of operating the cooling equipment at full capacity, thereby providing the maximum amount of dehumidification. The humidity control is connected between the high and low temperature contacts of the two-stage thermostat. If the temperature should drop too low as a result of operating at full capacity, the thermostat will shut off the unit when the thermostat breaks its first stage or low temperature contact.

Unit Ventilator Control

The Unit Ventilator is a self-contained room ventilating machine that takes a quantity of outside air, recirculated air, or a mixture of both and cleans, tempers or heats, diffuses, and distributes it throughout the room.

The primary functions of a Unit Ventilator are as follows:

1. To supply a given minimum amount of outside air for ventilation in accordance with the best practice and the requirements of the state law.
2. To heat the air to approximately room temperature if the unit is intended for ventilation only, or to a higher temperature if the unit is to take care of all or part of the heat losses of the room.
3. To control the temperatures of the delivered air to prevent both cold drafts and overheating.
4. To deliver air to the room in such a manner that good distribution is obtained without drafts.
5. To recirculate room air for heating when ventilation is unnecessary.
6. To clean the air supplied to the rooms by means of dry or viscous type filters.
7. To perform all its functions without objectionable noise.

Two general types of systems utilizing unit ventilators are in use today, namely:

1. **Split System.**
2. **Combined System.**

The "split system" consists of one or more unit ventilators which are used primarily for ventilation, with auxiliary direct radiation to offset the heat transmission losses of the building.

The "combined system" employs the unit ventilator alone to not only supply sufficient heat for ventilation air, but for the heat transmission losses as well. In this case the direct radiation is omitted altogether.

CLASSIFICATION OF UNIT VENTILATORS

Unit Ventilators may be classified under two major heads, i.e., Class A and Class C units, differing both in constructional features and in the method of control applied.

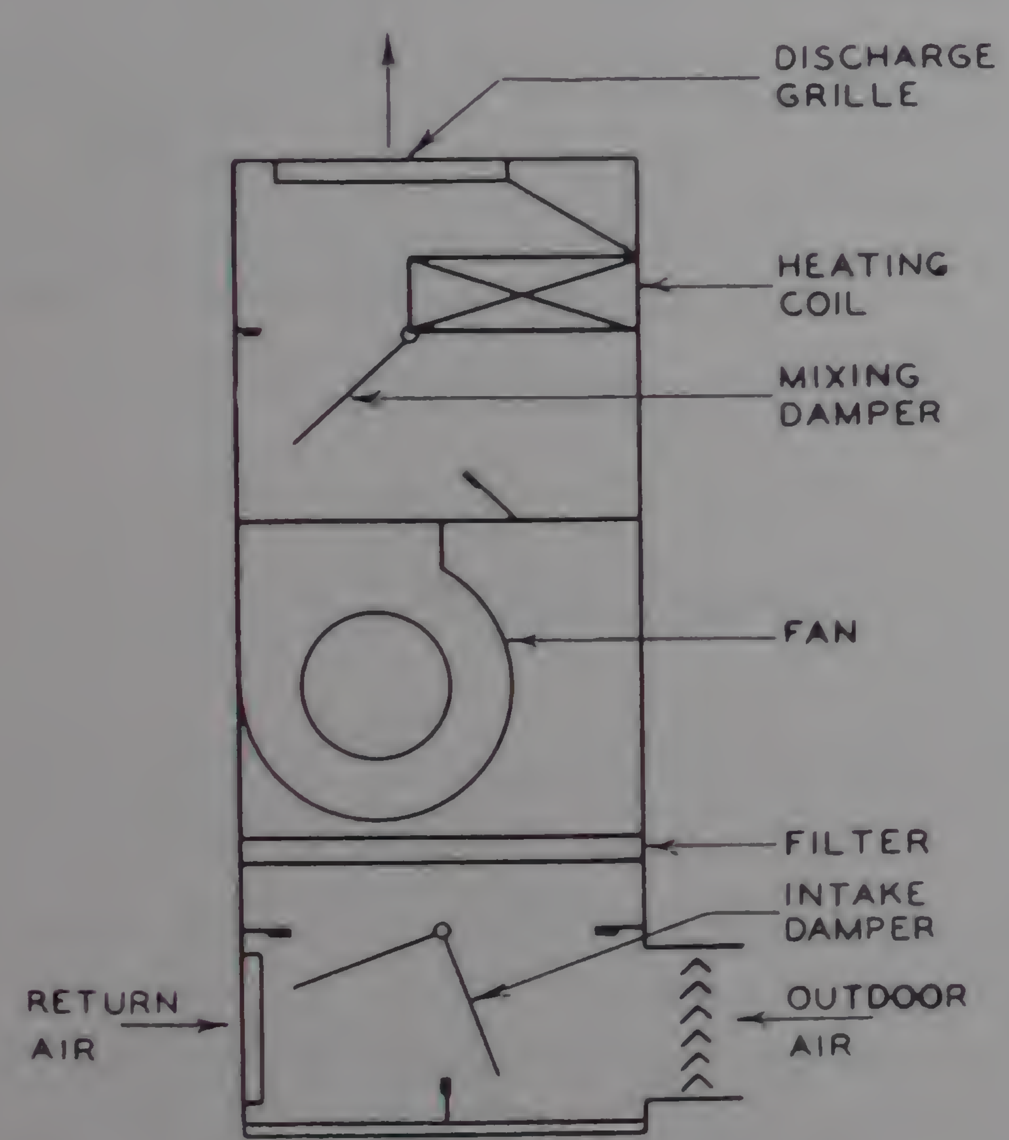


Figure 1

Class A Units

Fig. 1 illustrates schematically the constructional features of a typical Class A unit.

It will be noted that the salient features of this type of unit are the two sets of dampers whereby control of temperatures is effected. The combined fresh and recirculated air damper governs the relative amounts of outside and room air admitted to the unit, and in addition closes off the outside air supply, admitting only recirculated air during the warm-up period. The mixing or by-pass damper at the heating coil controls the temperature of the air discharged to the room by varying the relative quantities of air passed through and around the heating coil. The steam coil is in some cases permitted to run wild, although it is preferable to control the steam supply to preclude the possibility of heat from the coil leaking past the damper into the by-pass chamber during periods of maximum cooling. Under these conditions it is preferable to close the steam valve at this point in the cycle.

When the fan is stopped, steam is supplied to the heating coil, the by-pass damper is closed, the fresh air damper is closed and the recirculating damper is opened, permitting the unit to operate as a direct radiator.

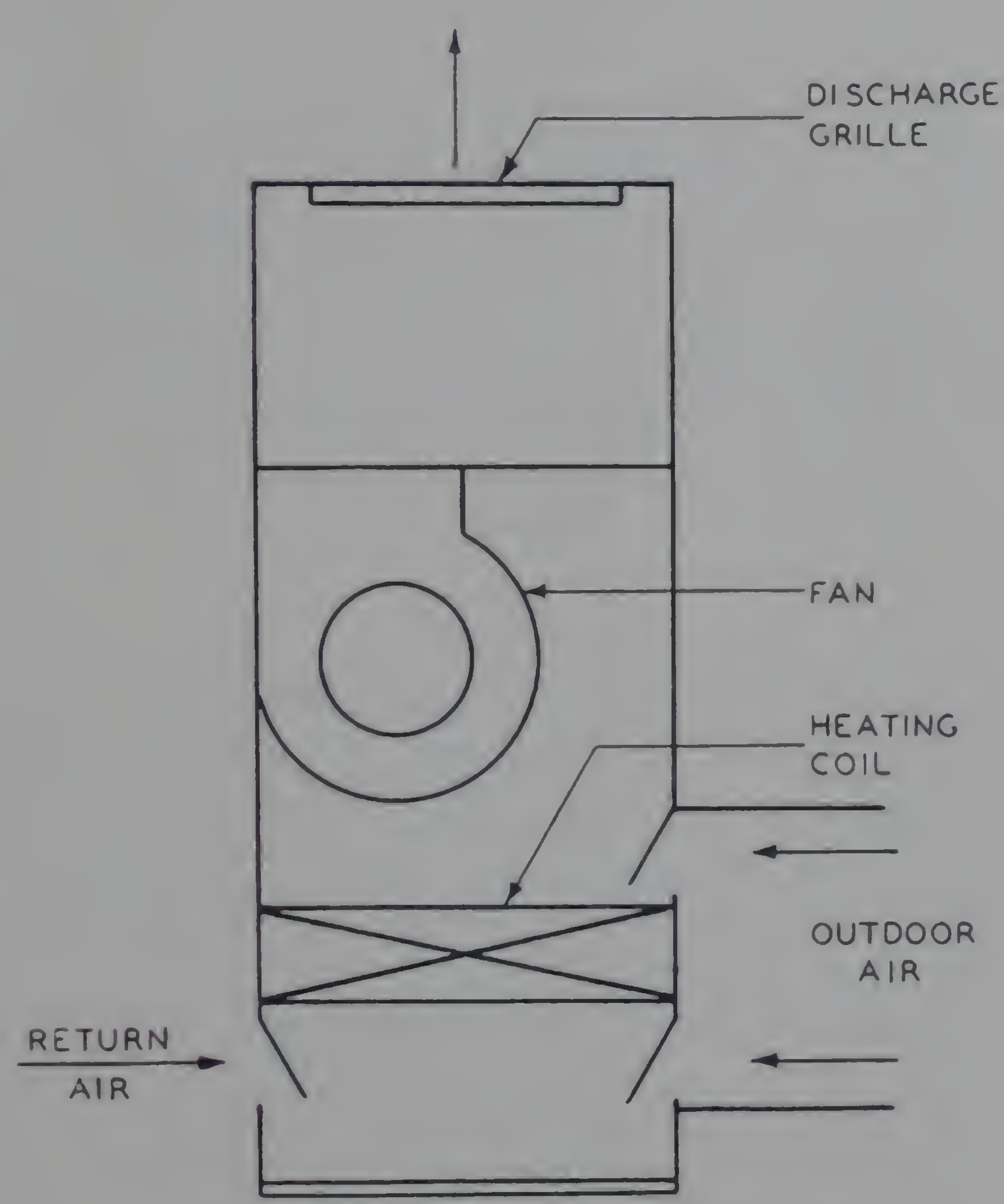


Figure 2

Figure 2 illustrates another design of Class A or damper type unit. All return air passes through the heating coil, however outdoor air can be by-passed around the heating coil.

During the heating up cycle both outdoor air dampers are closed so that the unit handles only recirculated air. As the temperature rises the minimum outdoor air damper **below** the heating coil opens. On a further rise in temper-

UNIT VENTILATOR CONTROL

ature the outdoor air damper **above** the coil modulates open and the minimum outdoor air damper modulates closed.

When maximum cooling is required, the recirculated air damper is closed, the steam valve is closed, and all outdoor air is brought in above the coil.

Upon stopping the fan, the outdoor air dampers are both closed, the steam valve opens, and the recirculated air damper is opened.

Class C Units

Fig. 3 illustrates schematically the construction features of a typical Class C unit.

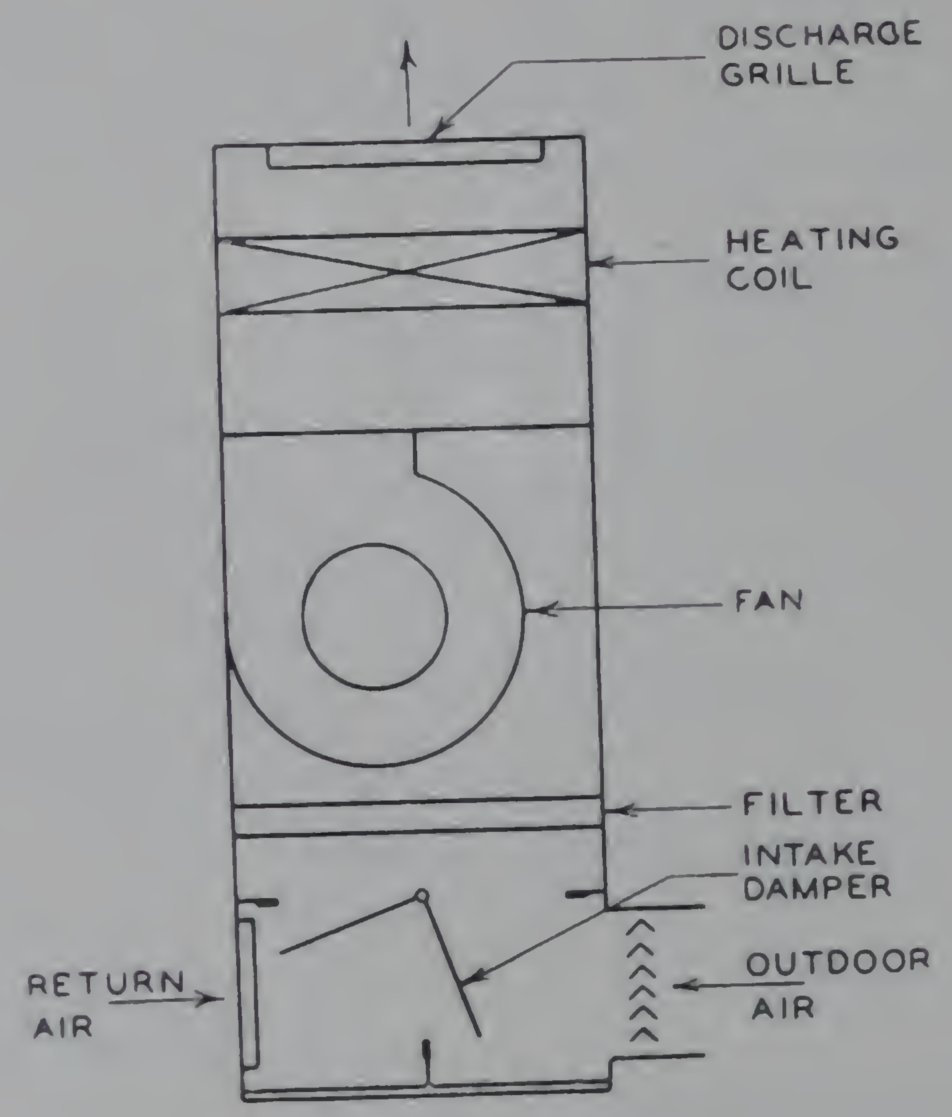


Figure 3

It will be noted that the chief difference between the Class A and Class C units lies in the absence of the by-pass or mixing dampers. All of the air is allowed to pass through the heating coil with temperature control being effected by modulating the steam valve and fresh and recirculated air damper in sequence. In the case of shutdown, the steam valve is opened wide and the fresh air damper is closed, permitting the unit to act as a radiator.

Either electric or pneumatic controls may be applied to unit ventilators.

PNEUMATIC CONTROL

Pneumatic control systems are available for unit ventilator applications in all standard and special cycles of operation. The simplicity of operation and ease of installation and adjustment of the Gradutrol system cause it to be readily applicable to special cycles and to units which are more or less special with regard to the design itself.

Class A Units

There are two control arrangements which are commonly used with Class A or damper type units. The cycles differ because of the difference in construction between the two types of Class A units which are available.

M-H-R Cycle D1

Units utilizing M-H-R Cycle D1 require two damper motors, one for operating the by-pass damper and the other to control the outdoor and return air dampers. Steam valves are used for controlling the supply to the heating coil and are supplied with springs so that they move only during certain periods of the cycle.

A graduate acting thermostat adjusted for approximately a four degree differential controls both the unit ventilator and the auxiliary radiation on split systems. The auxiliary radiation is used only during the heating-up period.

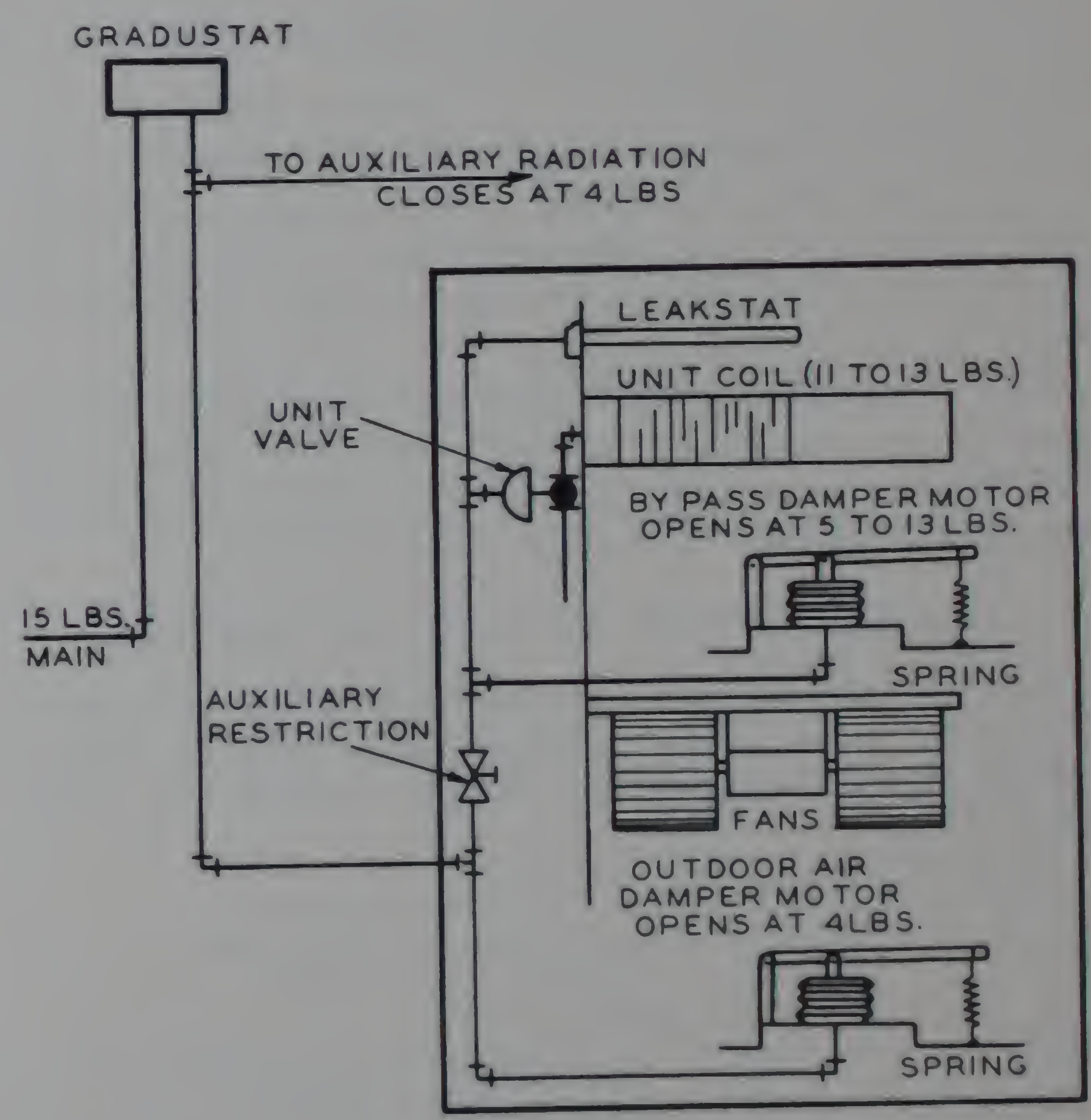


Figure 4

The system as shown in Figure 4 provides the following sequence:

1. As the unit is started up, with the room temperature below the setting of the thermostat, the auxiliary radiators and unit coil will be full of steam, and the outdoor air damper will be closed. The by-pass damper will be closed thereby sending all the recirculated air through the heating coil in order to provide full capacity for heating-up.

UNIT VENTILATOR CONTROL

2. As the room temperature enters the range of the thermostat the auxiliary radiation is closed off and the outdoor air damper is opened wide.

3. On a further rise in temperature the by-pass damper is modulated open so that air by-passes the heating coil.

4. To provide maximum cooling, the heating coil valve is shut down after the by-pass damper is completely open.

M-H-R Cycle D2

A graduate thermostat adjusted for about a four degree differential controls both the unit ventilator and the direct radiation. One damper motor controls the outside air and return air dampers, and a steam valve controls the supply to the heating coil. The springs in the valves are specified so that they move only during a certain part of the cycle.

Figure 5 illustrates a system for accomplishing Cycle D2 in the following manner:

1. With the room temperature below the thermostat setting, when the unit is started up valves will be open and steam will be in the heating coil and direct radiation. The recirculated air damper will be wide open and both outdoor air dampers will be closed.

2. As the room temperature enters the range of the thermostat, the minimum fresh air intake below the heating coil will open.

3. On a further rise in temperature the direct radiation will be shut off.

4. As the temperature rises further the by-pass fresh air damper **above** the heating coil modulates open and the minimum fresh air damper modulates closed.

5. Finally to provide maximum cooling the valve on the heating coil modulates closed. At this time all the air delivered by the unit is fresh air which has by-passed the heating coil.

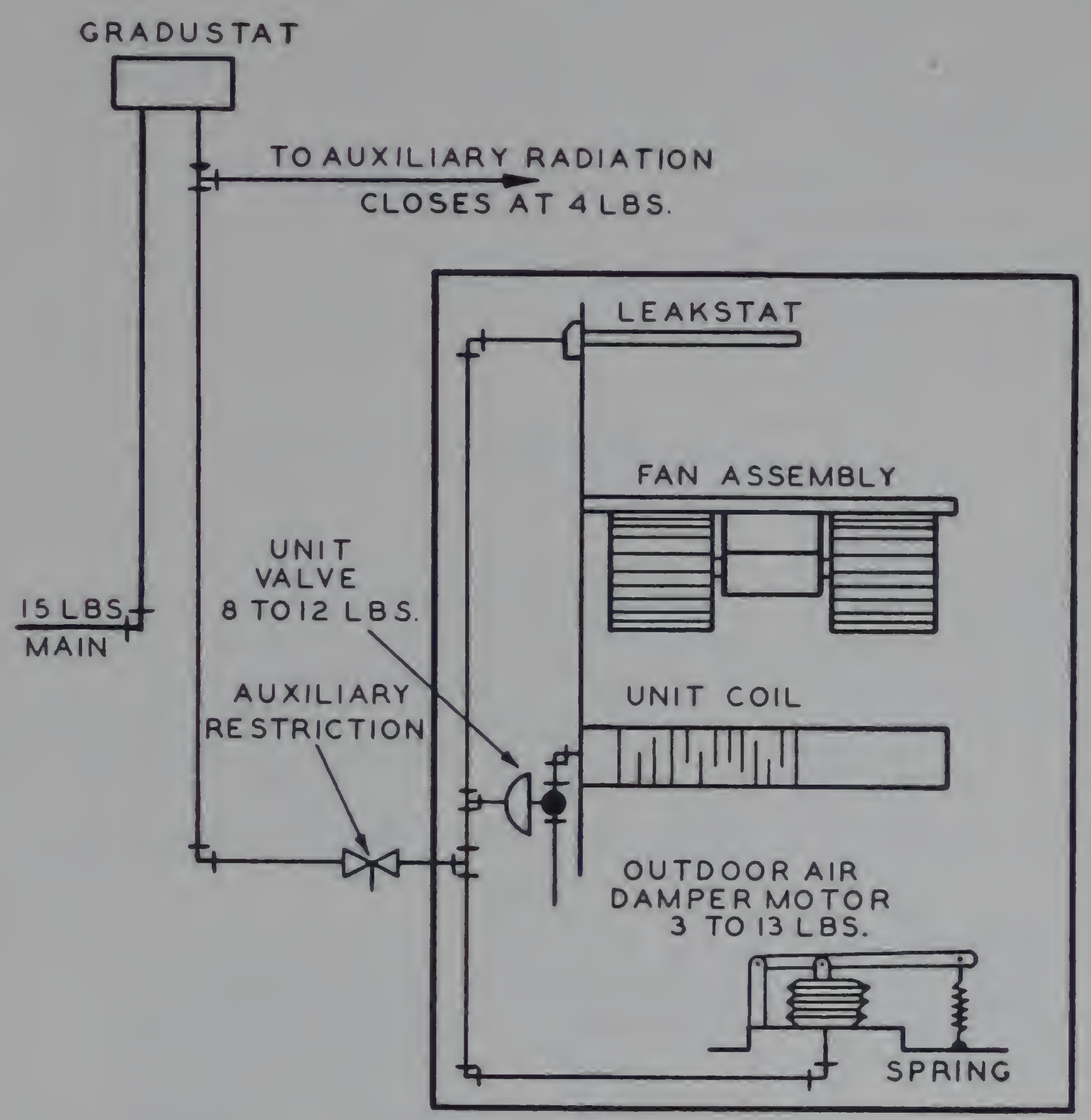


Figure 5

Class C Units

There are three cycles of operation for Class C units which have become more or less standard among the various unit ventilator manufacturers. These are known by the following designations:

MHR	Peerless	Nesbitt	Sturtevant	Trane
No. 1	1	F	2	A
No. 2	2	A	1	C
No. 3	3	O	3	B

All of these cycles require motors for the intake and recirculating dampers which will move only at definite periods during the cycle. They all require valves for the unit ventilator heating coil equipped with throttling disc nuts and spring arrangements so adjusted that the valves will move only during definite periods. If auxiliary radiation is used, as in a "split system," the radiator valves must be so adjusted that they will close at about 4 pounds pressure on the branch line of the thermostat, or before the unit ventilator begins its cycle of operation.

A graduate thermostat with a four degree differential is used to control the motors and valves. In most cases a leakstat or airstream thermostat is also used to prevent the temperature of the discharge air from dropping sufficiently low to produce drafts.

Following is a description of the method of accomplishing the three standard cycles of operation with pneumatic controls.

UNIT VENTILATOR CONTROL

M-H-R Method No. 1—100% Outside Air

Fig. 6 illustrates the method of accomplishing this cycle of operation.

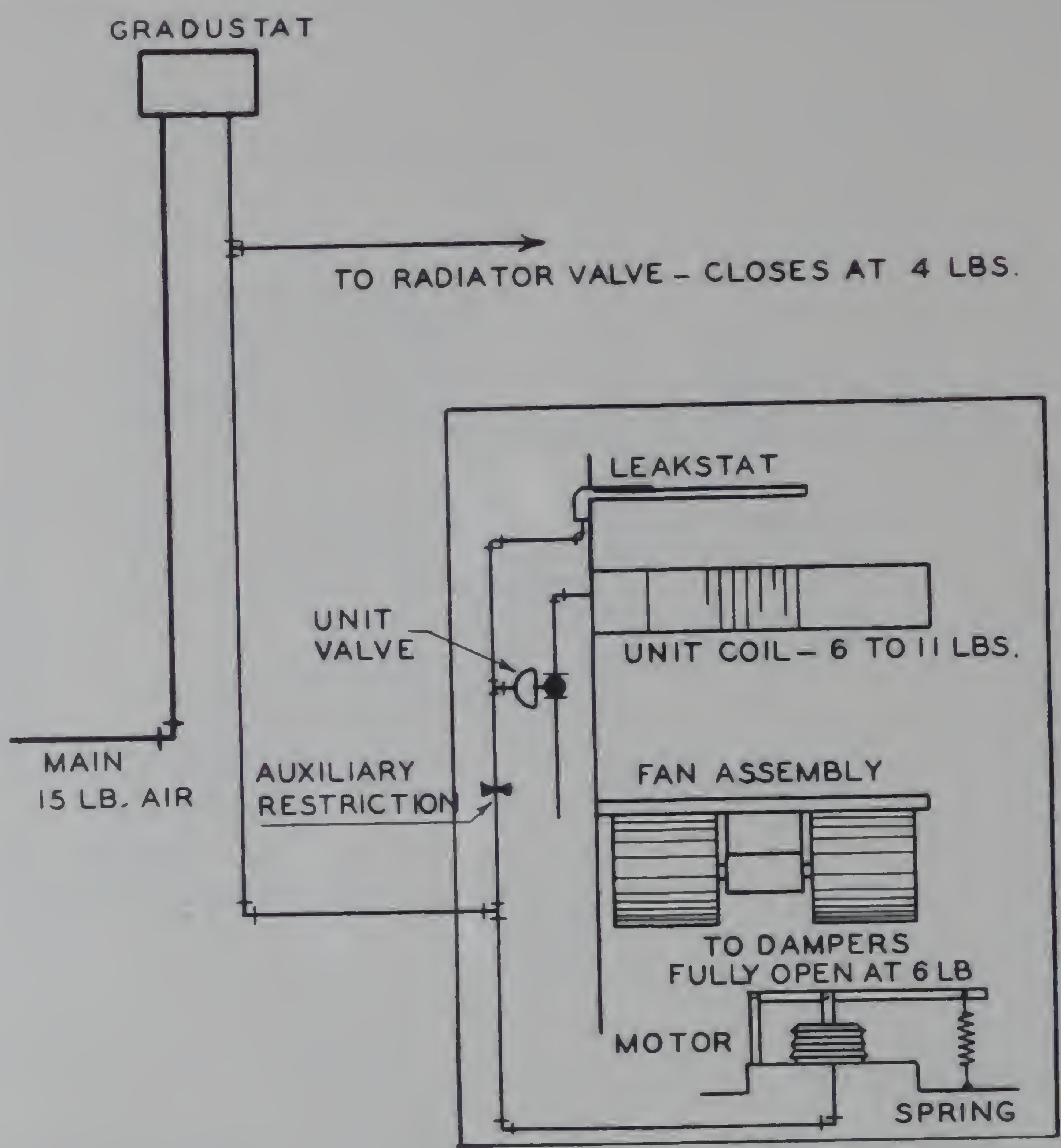


Figure 6

1. When the unit is started up, steam is supplied to the radiator and to the auxiliary radiation (if used) and the intake damper is closed to outside air. The unit recirculates room air until the room temperature approaches the desired point.

2. As the room temperature enters the range of the thermostat, the branch line pressure is built up as the thermostat closes its port. The auxiliary radiator valves close completely at a pressure of four pounds. The intake damper motor is so arranged that the damper will be opened to 100% outdoor air at a branch line pressure of five pounds.

3. From this point on the steam valve controls the room temperature. As the temperature rises and the branch line pressure increases to six pounds, the unit valve begins to close and is fully closed at eleven pounds. The airstream thermostat or leakstat located above the coil prevents the discharge temperature from dropping to a point which would cause drafts by modulating the steam valve open.

4. An auxiliary restriction, which is located so that the connections to the unit coil valve and the airstream stat are on the restricted side, prevents the leakstat from breaking down the branch line pressure of the room thermostat and operating the intake damper motor or the radiator valves.

M-H-R No. 2—Fixed Minimum Quantity of Outdoor Air During Occupancy

Fig. 7 illustrates the method of accomplishing this cycle of control.

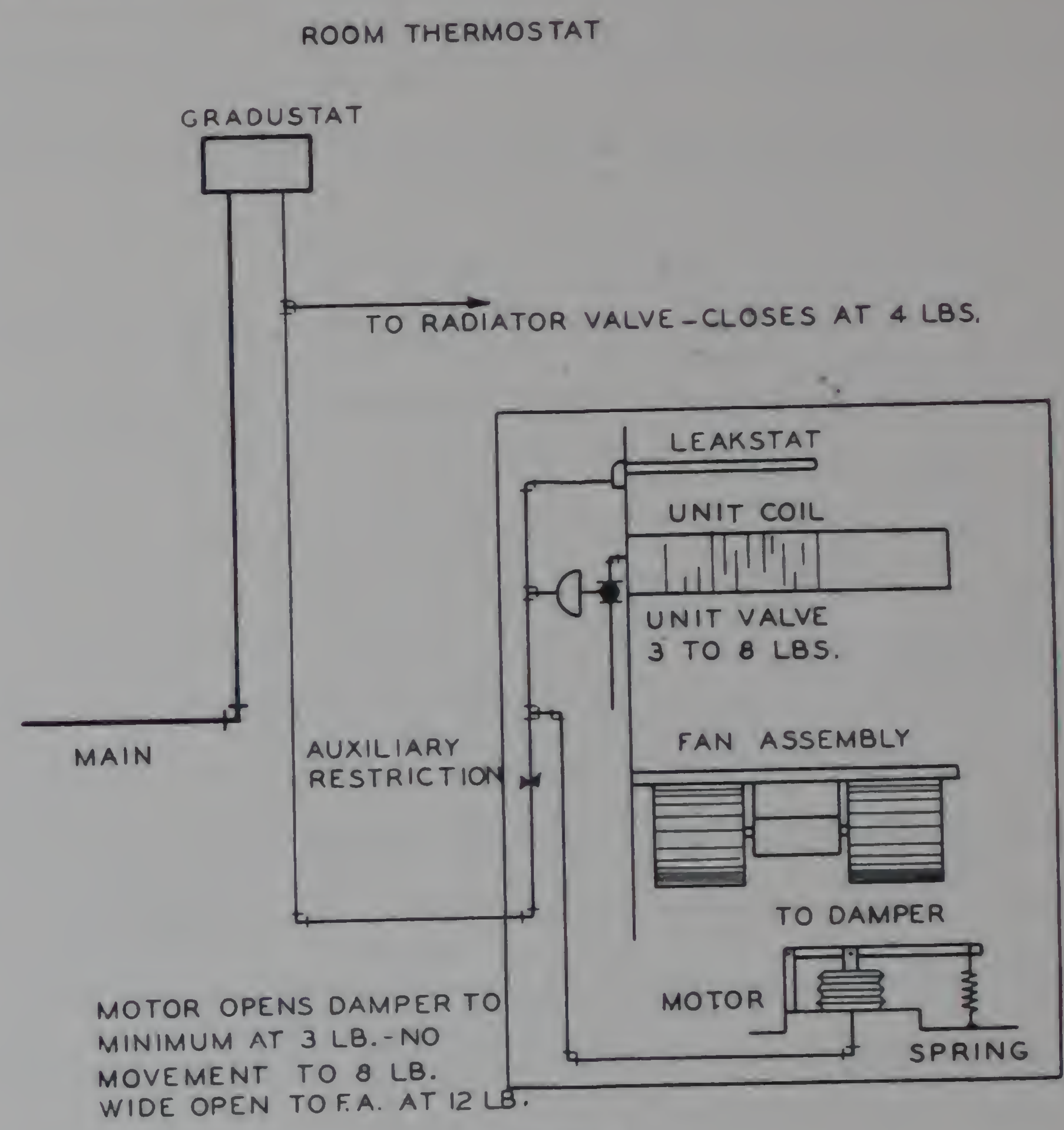


Figure 7

1. When the unit is started up, steam is supplied to the unit coil and the auxiliary radiation (if used), and the intake damper is closed to outside air. Room air is recirculated until the room temperature approaches the desired point.

2. On a rising room temperature the branch line pressure rises. The intake damper opens to its minimum position when three pounds pressure has accumulated on the branch line. The radiator valve (if used) is fully closed when four pounds pressure has accumulated. The unit valve starts to close at three pounds pressure and is fully closed at eight pounds pressure.

3. As long as the fixed minimum amount of fresh air is sufficient to prevent overheating, the damper remains in this position. If the room temperature continues to rise, the branch line pressure rises further to modulate the outdoor air damper from its minimum position to a wide open position with full pressure on the branch line.

4. The air stream thermostat or leakstat, located over the unit coil on the steam supply side, prevents the discharge temperature from dropping to a point which would produce drafts by modulating the intake damper and coil valve.

5. An auxiliary restriction is installed in the branch line of the room thermostat so that the connections to the damper motor, the unit coil valve and the leakstat are all on the restricted side of the branch. This prevents the air stream thermostat from breaking down the pressure in the room thermostat branch line and opening the radiator valve.

UNIT VENTILATOR CONTROL

M-H-R No. 3—Variable Amount of Outside Air

Fig. 8 illustrates the method of accomplishing this cycle of control.

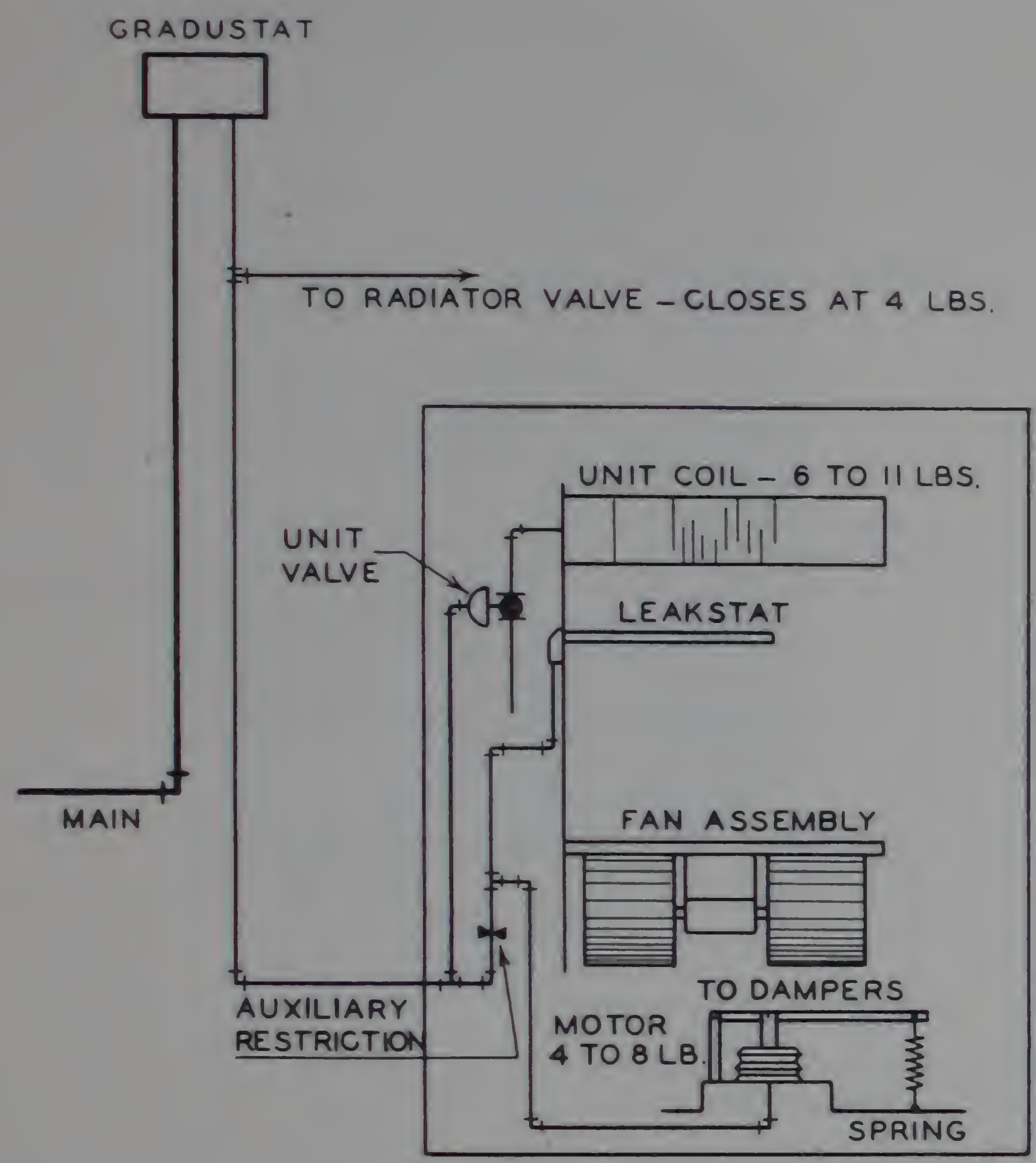


Figure 8

1. When the unit is started up, steam is supplied to the unit coil and the auxiliary radiation (if used), and the intake damper is closed to outside air.
2. As the room comes up to temperature the auxiliary radiator valve (if used) closes after four pounds pressure has accumulated on the thermostat branch line. The unit coil valve starts to close at six pounds and is fully closed at eleven pounds.
3. The air stream thermostat is located below the unit coil just above the fan discharge. The air stream thermostat starts to function as the room comes up to temperature and the branch line pressure rises to four pounds and positions the intake damper so as to take a mixture of outside and recirculated air to deliver a constant temperature to the unit coil.
4. The intake damper motor operates between four and eight pounds. When the steam valve is closed and the unit is operating as a ventilating machine, the discharge temperature is determined by the position of the intake damper.
5. In this case the auxiliary restriction is located so that the connections to the intake damper and the air stream thermostat are on the restricted side. The air stream thermostat may then operate the intake damper motor without breaking down the pressure in the unit valve and radiator valve branch line, causing them to open.

Auditorium Type Units

Large units for heating and ventilating auditoriums, gymnasiums, etc., are controlled on the various cycles as detailed above. There are numerous variations of these cycles, however, and the motors and valves must be arranged with special springs, etc., to accomplish the cycle as specified. It is often necessary to use a graduate relay in order to supply sufficient air for the control at the units, due to the larger motors and valves involved.

Manual Control

It is often desired to control unit ventilators manually, chiefly for economic reasons, since it is realized that greater efficiency and increased comfort are obtained if the human element is entirely eliminated through the medium of automatic controls. Linkage assemblies have been developed for several of the Class C unit ventilators to accomplish M-H-R cycles No. 1 and No. 2. The sequence of operation of the intake damper and the steam valve is identical with that obtained by the use of automatic controls.

ELECTRIC CONTROL

Class A Units

There are several cycles which are commonly used to control the operation of a by-pass unit ventilator, differing in the method of controlling the fresh air damper. Usually two motors are required on this type of unit, one of them for the intake damper and one for the mixing damper. The most common cycles operate as follows:

Fig. 9 illustrates the controls and wiring for the first cycle.

1. With power off, the fan is shut down, the steam valve is open, the fresh air damper is closed, the recirculated air damper is open and the by-pass damper is closed, causing room air to pass through the coil unit by convection.

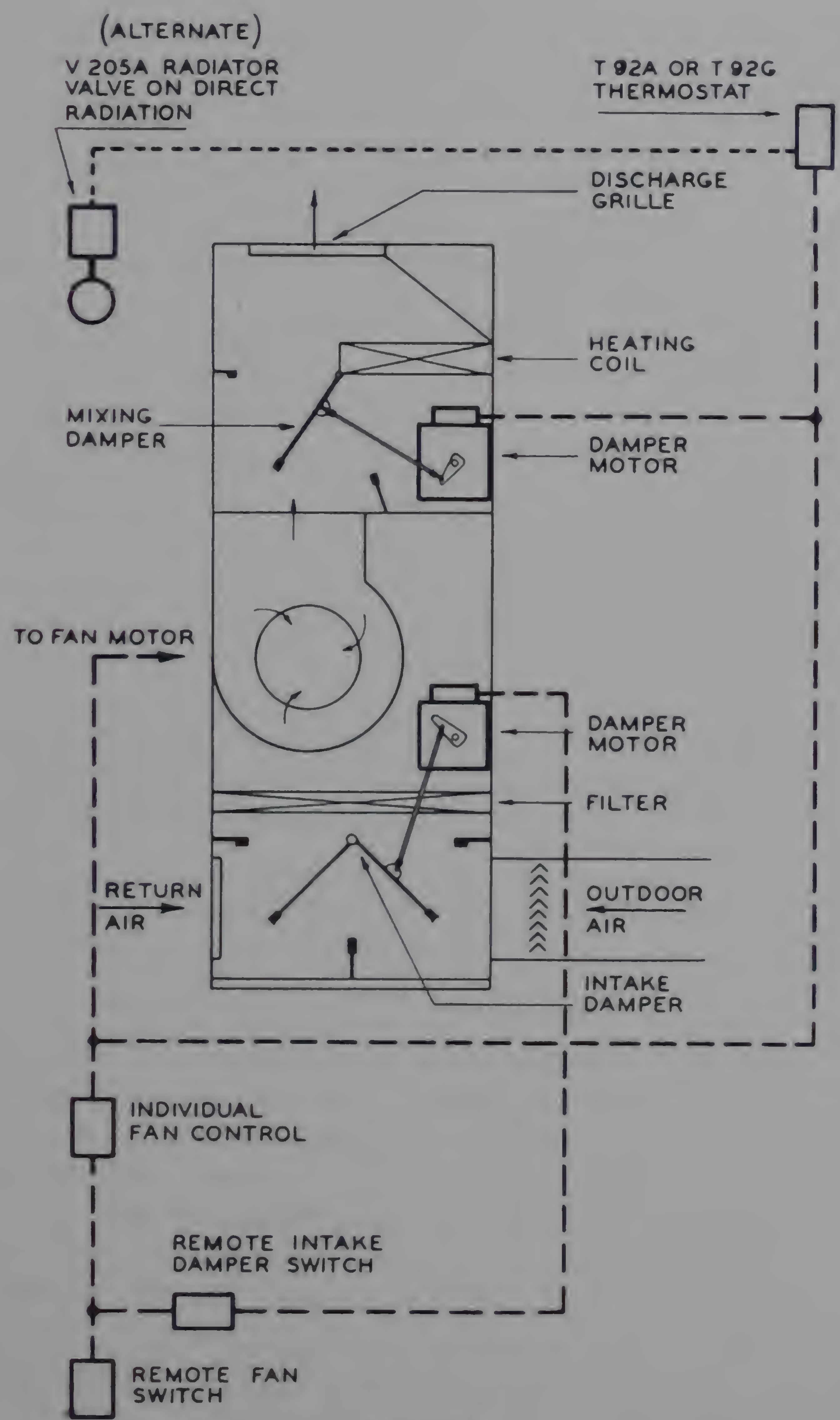


Figure 9

UNIT VENTILATOR CONTROL

2. During the morning pick-up period, the unit operates with the fresh air damper closed and the recirculated air damper open. The by-pass damper is controlled from the room thermostat to vary the relative quantities of air passed through and around the coil in accordance with the demand for heat.
3. Shortly before the room is to become occupied the fresh air damper is opened and the recirculated air damper closed by means of a manual switch, either at the unit or remote, to supply ventilation air. Temperatures are then maintained during periods of occupancy by modulating the mixing damper motor from the room thermostat as before.

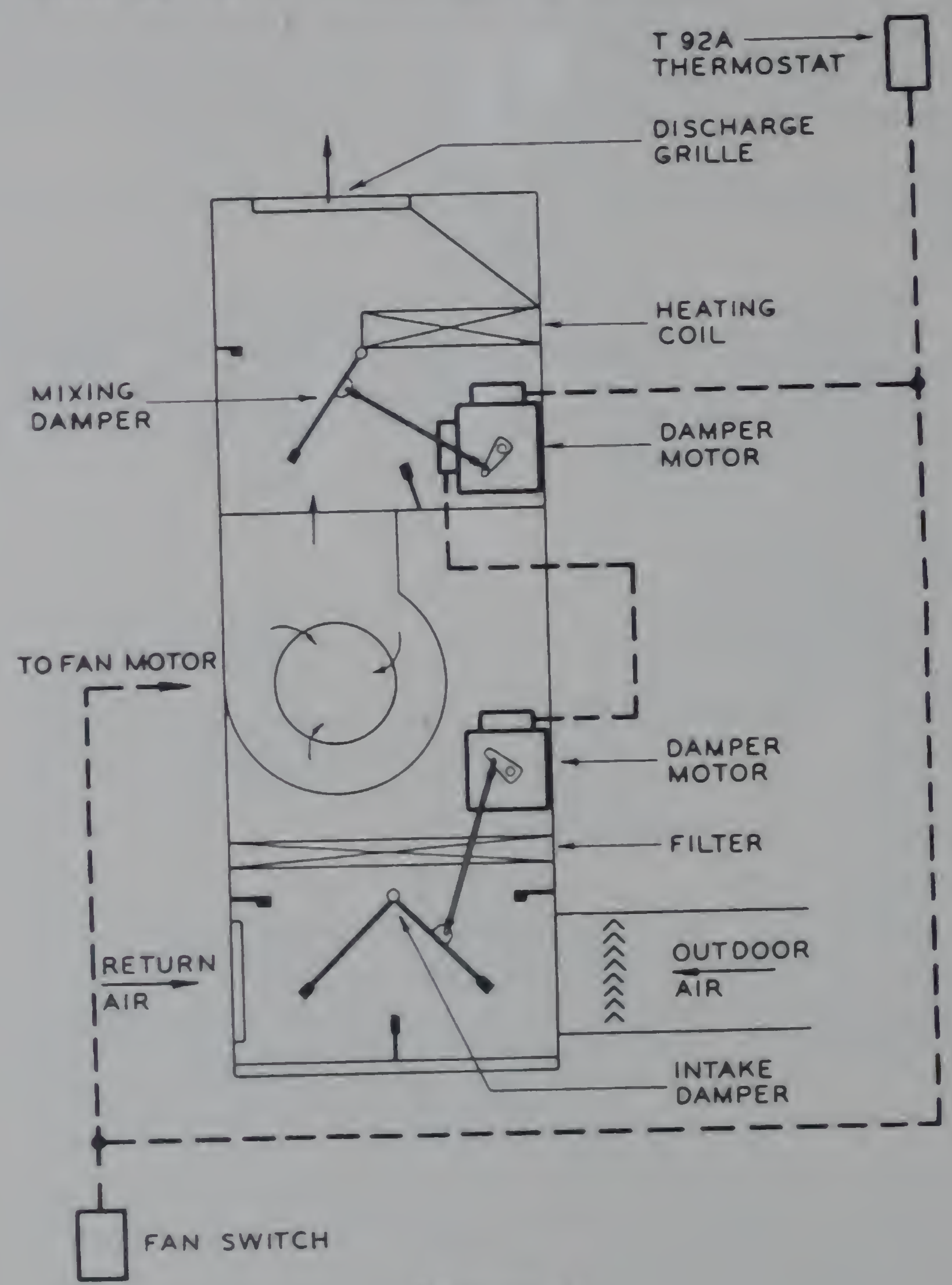


Figure 10

It is often desirable to have the intake damper operate automatically from room temperature rather than a manual switch. Fig. 10 illustrates the hookup for this cycle of control.

In this case the power for the intake damper motor is carried through an auxiliary switch on the mixing damper motor.

1. When the unit fan is started the switch will be broken so that the fresh air damper will be closed.
2. As the room temperature rises to approximately 70° the auxiliary switch will complete its circuit as the mixing damper modulates to open the by-pass around the coil, causing the intake damper to open to 100% fresh air. Room temperatures are maintained by modulating the mixing damper as before.

The third cycle provides for controlling the intake damper to provide 100% fresh air whenever the system is in operation. Fig. 11 illustrates this cycle.

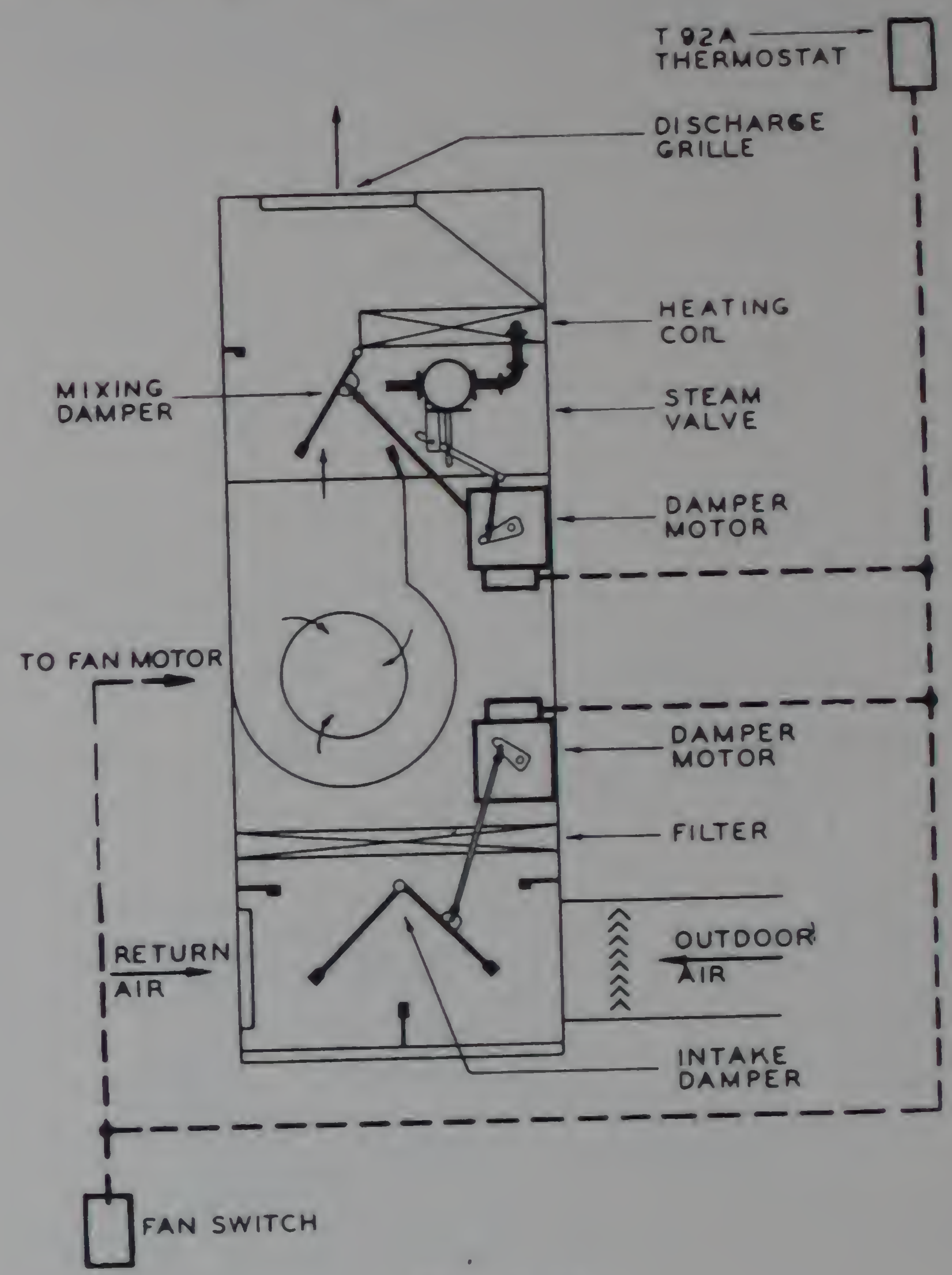


Figure 11

The power for the intake damper motor is taken directly from the fan side of the fan starting switch so that whenever the fan is in operation the intake damper will be open to 100% fresh air.

With all cycles of control, steam is normally supplied to the units continuously during the heating season. In mild weather, especially when the sun is shining in the windows, the temperature in the room rises and no heating is required. The by-pass damper will be wide open to discharge 100% outside air for cooling. It is possible that heat from the coil will leak into the by-pass chamber, reducing the cooling effect of the outside air.

For this reason a linkage has been developed to provide sequence operation of the steam valve and mixing damper using one motor. The cams are usually arranged to close the steam valve after the by-pass has opened wide.

If auxiliary direct radiation is used in conjunction with unit ventilators the control of the steam supply to the radiators is effected by two-position electric radiator valves or modustats. If electric radiator valves are used, a modulating room thermostat, which has a set of Series 20 contacts in addition to the Series 90 potentiometer, controls both the radiator valves and the unit ventilator. The thermostat is so adjusted that on a rising room temperature the Series 20 contacts first close the radiator valve, after which the potentiometer controls the operation of the unit ventilator.

If a self-contained radiator valve is used, a modulating thermostat without extra Series 20 contacts may be used, as shown in Figs. 10 and 11. The radiator valve is adjusted to close off the steam to the radiator at a temperature just below that at which the thermostat will begin to operate the unit ventilator, so the direct radiation will be off before the unit starts its cycle.

UNIT VENTILATOR CONTROL

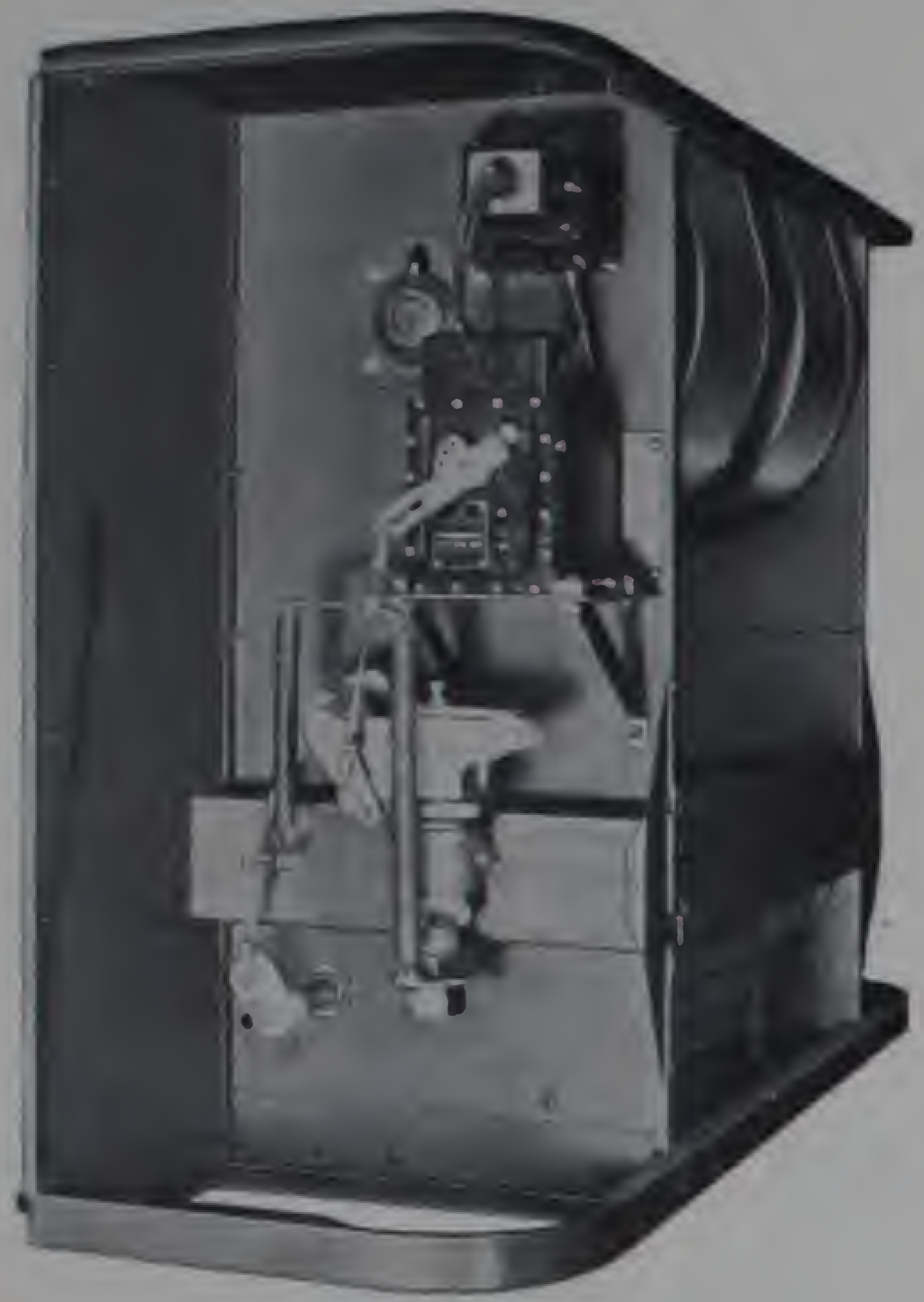


Figure 12

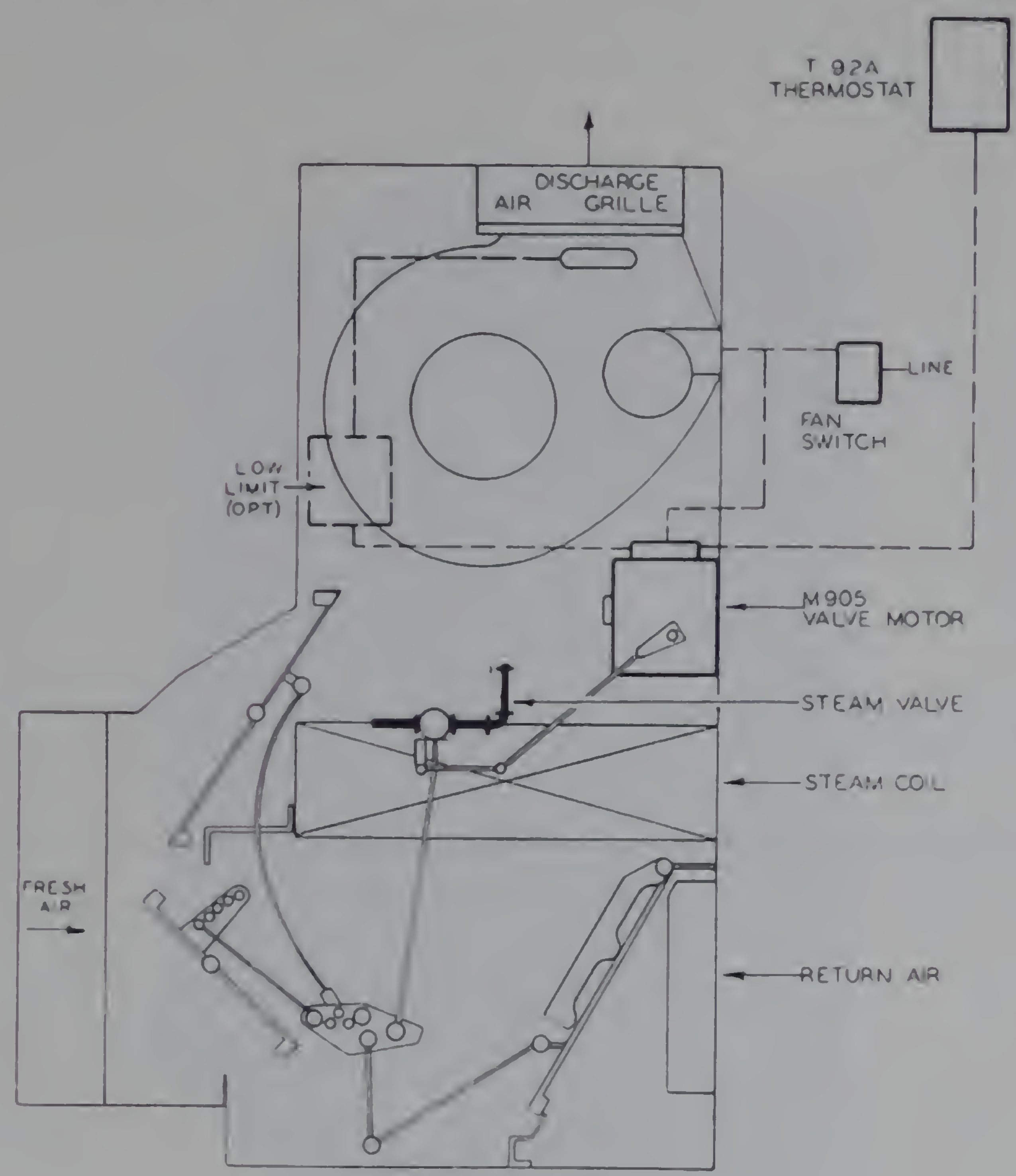


Figure 13

The Herman Nelson Type D damper controlled unit, although classified as a Class A unit, uses a somewhat different method of control than do the others in this classification. A single spring return type modulating motor is used to control the steam valve, outside air damper, recirculated air damper, and by-pass damper at the command of the modulating room thermostat.

Fig. 12 illustrates the linkage arrangement which has been developed for this unit, and Fig. 13 illustrates the schematic control system for this cycle.

The operation of this unit is as follows:

1. When the room temperature is below normal the unit and the auxiliary radiator (if used) are delivering their maximum heating capacity. The unit is circulating room air only.
2. When the room temperature reaches a predetermined point the thermostat causes the lower fresh air damper to open to admit the desired quantity of fresh air for ventilation.
3. If the room temperature continues to rise the steam supply to the auxiliary radiator (if used) is shut off. Following this the upper outdoor air or by-pass damper modulates open and the lower outdoor air damper closes, causing outside air to be introduced above the heating coil.
4. If the room temperature continues to rise, the steam valve is closed, giving a maximum of cooling.

Class C Units

There are three cycles of operation for Class C units which have become more or less standard among the various unit ventilator manufacturers. These are known by the following designations:

MHR	Peerless	Nesbitt	Sturtevant	Trane
No. 1	1	F	2	A
No. 2	2	A	1	C
No. 3	3	O	3	B

M-H-R methods No. 1 and No. 2 require but one spring return type modulating motor to operate the intake dampers and the steam valve in sequence. Method No. 3 requires the use of two motors, one to operate the steam valve and the other to operate the intake dampers.

Fig. 14 shows a side view of a typical application of a linkage for methods No. 1 and 2 to a Class C unit.

Following is a description of the various cycles of control:

M-H-R No. 1—100% Outside Air

Fig. 14 illustrates the controls used to accomplish this cycle of operation:

1. If the room temperature is below normal, as in the morning, when the fan is started the steam valve is open and the intake damper closes off all outside air so that room air is recirculated through the coils.
2. When the temperature in the room rises to a predetermined point (usually about 68°) the outside air damper opens and the recirculated air damper closes so that 100% fresh air is circulated.
3. On a further increase in room temperature the steam valve modulates toward its closed position.
4. Room temperatures are maintained by modulation of the steam valve from a room thermostat.

A low limit controller is located with its sensitive element above the heating coil and is wired into the circuit in such a manner as to prevent the discharge temperature from dropping below a certain predetermined point by modulating the steam valve open. The temperature of the discharge from the unit is relatively high when the fan is not operating and steam is being supplied to the unit. Because of these high temperatures at the bulb of the instrument, an abnormal pressure may be built up in the bellows unless a special unit designed for this application is used.

UNIT VENTILATOR CONTROL

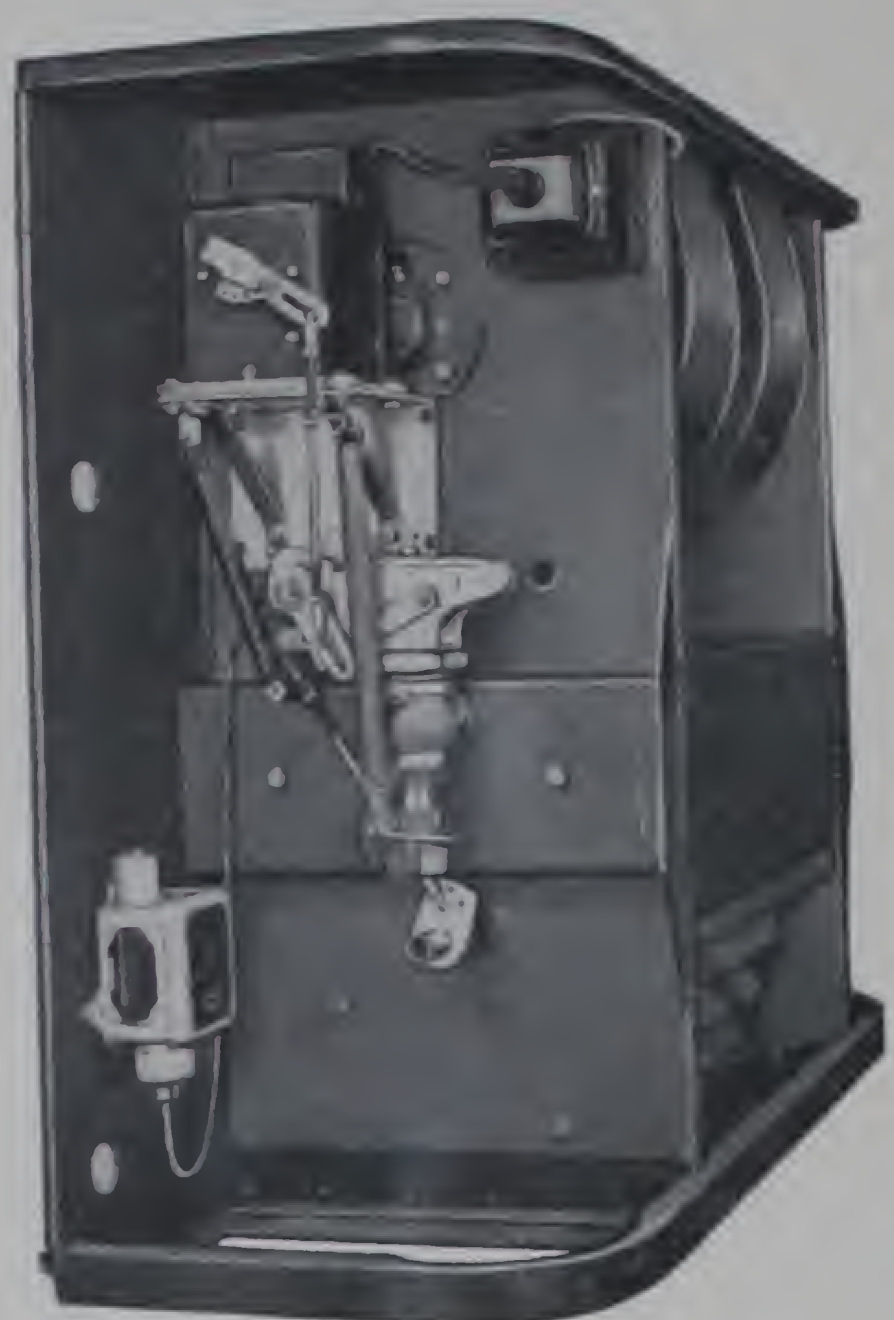


Figure 14

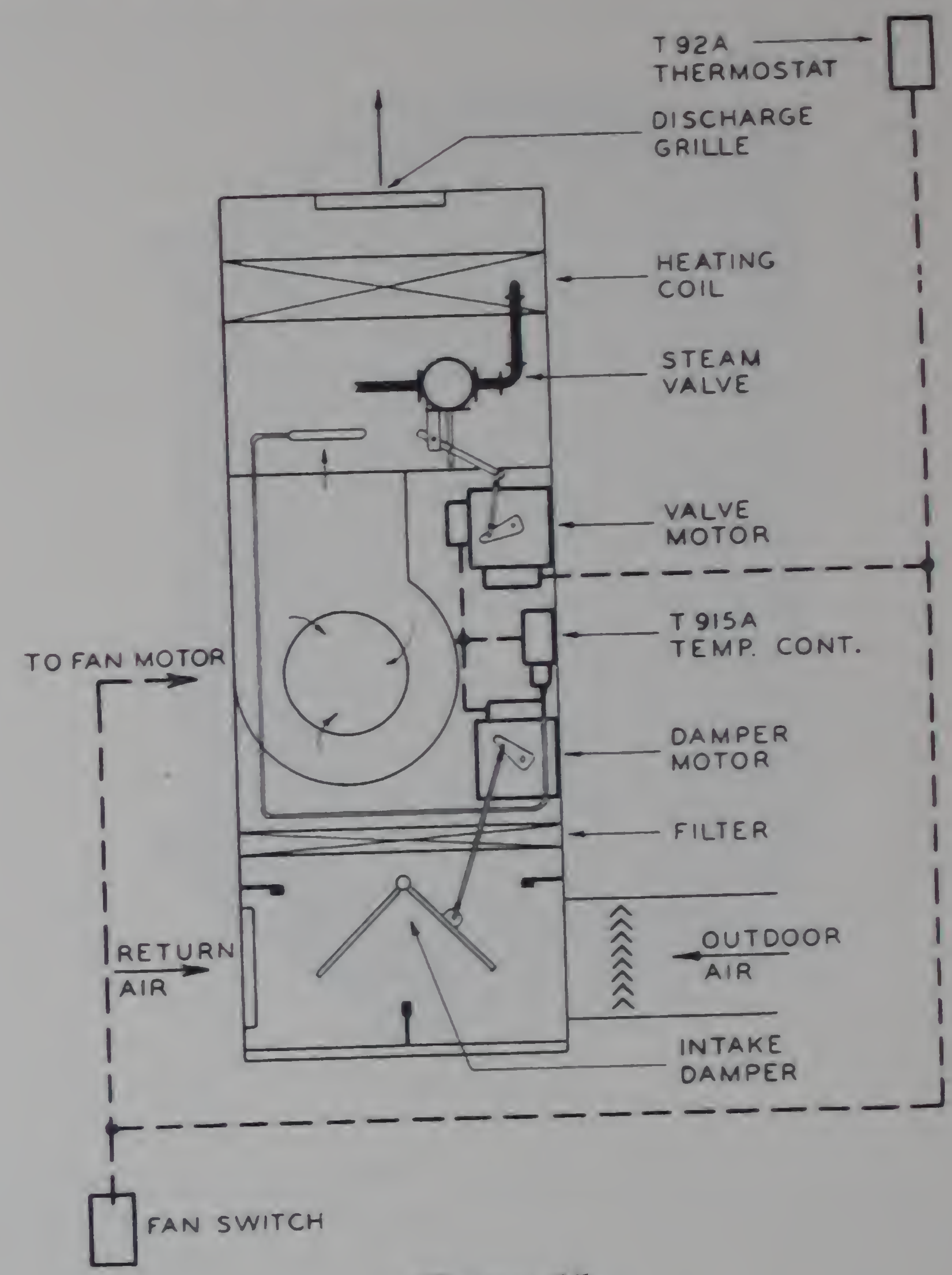


Figure 15

M-H-R No. 2—Fixed Minimum Outside Air.

The control equipment for this cycle is identical with that used for method No. 1 and is illustrated by Fig. 14, except for the fact that the position of the damper cams is changed.

1. The unit starts with the intake damper closed to outside air and the steam valve wide open.
2. When the room temperature rises to a predetermined point (usually about 68°) the outside air damper opens to its minimum position.
3. On a further rise in temperature the steam valve modulates toward its closed position and is fully closed at 70°.
4. As long as the fixed minimum quantity of air is sufficient to prevent overheating, the damper remains in this position. As the temperature rises above 70°, the damper modulates from its minimum position and is fully open to 100% outside air at 71°.

As in method No. 1, a low limit controller prevents the discharge temperature from dropping below a predetermined point to avoid drafts by closing the fresh air damper, opening the return air damper, and opening the steam valve.

M-H-R No. 3—Variable Outside Air—No Fixed Minimum.

Fig. 15 illustrates the controls necessary to accomplish this cycle of operation.

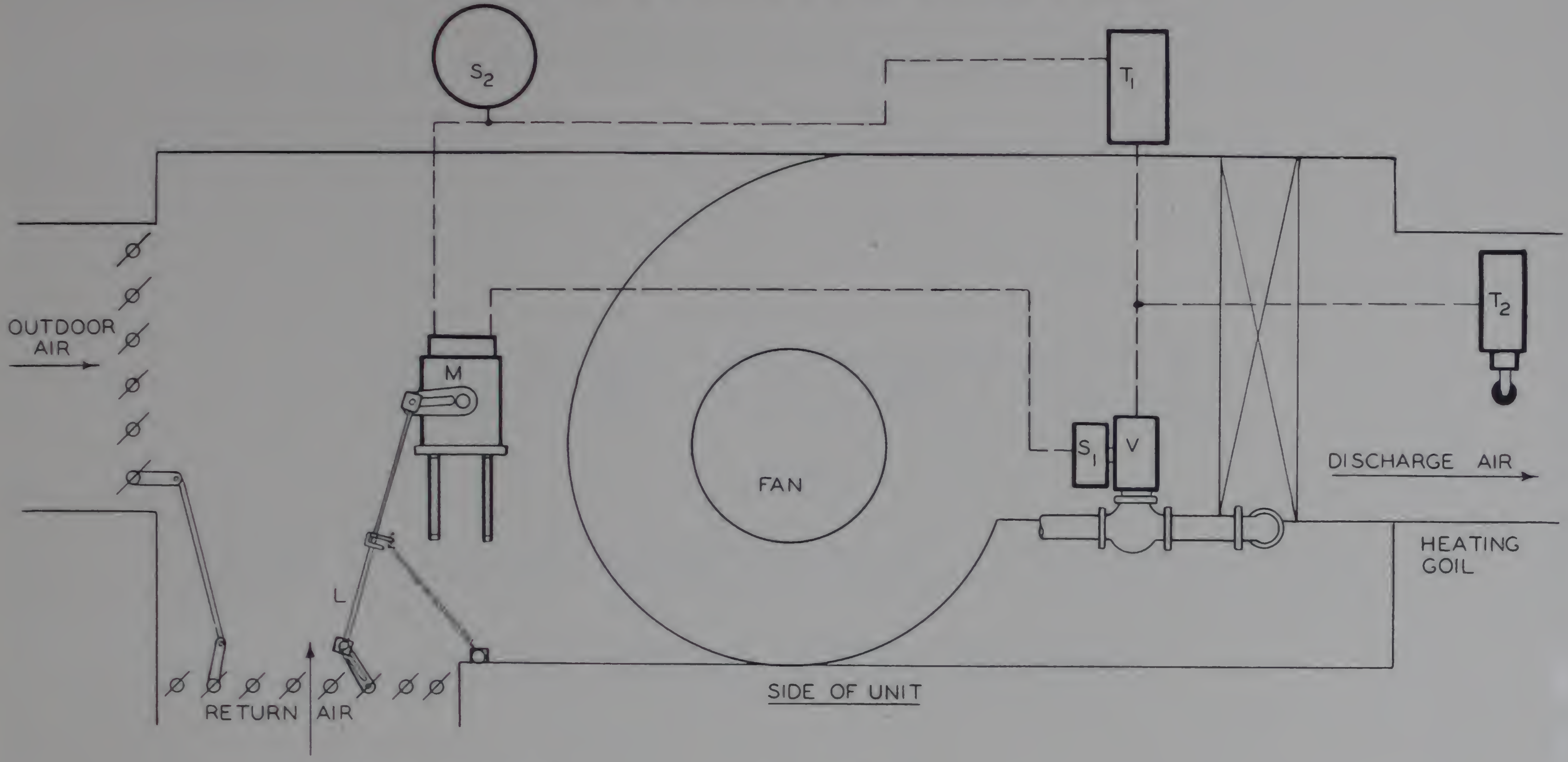
When the unit is started, the steam valve is open, the fresh air damper is closed and room air is recirculated during the warm up period.

1. When the room temperature reaches a certain predetermined point (usually about 67°), the steam valve starts to modulate toward its closed position.
2. As this occurs, an auxiliary switch on the valve motor makes contact, supplying power to the intake damper motor and permitting the remote bulb controller to assume command of it. The sensitive element is mounted ahead of the heating coil and the controller is set to maintain the temperature of the air entering the heating coil at 60°. This is accomplished by varying the relative quantities of outside and recirculated air admitted to the unit.
3. The position of the intake damper is a function of room and outside temperature rather than room temperature alone. Therefore two motors must be used for this cycle. The duct controller operates the damper motor independently of the valve until the unit is shut down, at which time the auxiliary switch breaks power to the motor, which then closes the outside air damper.

If auxiliary radiation is used in conjunction with the unit ventilator, a room thermostat, which has a Series 90 potentiometer and a set of Series 20 contacts, must be used. The Series 20 contacts will close the radiator valve before the unit ventilator begins to operate.

With all cycles, whenever the unit fan is stopped, the steam valve is opened wide and the outside air damper is closed, permitting the unit to operate as a radiator.

UNIT VENTILATOR CONTROL



T_1	THERMOSTAT (T92E)
T_2	TEMPERATURE CONTROLLER, LOW LIMIT (T915C)
M	DAMPER CONTROL MOTOR (M905A)
V	STEAM VALVE (K900)
S_1	AUXILIARY SWITCH (Q52)
S_2	DAMPER MINIMUM POSITION SWITCH (S93)
L	LINKAGE FOR INTERCONNECTION OF MOTOR AND DAMPER

Figure 16

Auditorium—Type Units

Large units for heating and ventilating auditoriums, gymnasiums, etc., are controlled on the various cycles with electric controls as detailed above. There are numerous variations of these cycles, however, and the exact cycle and size of unit determine the controls that are required.

M-H-R Method #2—Fixed Minimum Outside Air.

Figure 16 illustrates the controls necessary for a typical unit operating on this cycle of operation.

Control Sequence: Modulated control of steam valve with a set minimum discharge temperature. Two-position fresh air damper opening to a set minimum on an initial temperature rise; 100% modulated damper opening on a temperature rise indicating a need for cooling.

1. When the room temperature is below 68° (assuming the thermostat is set at 70° with a 4° differential) the maximum heat output is required and the apparatus is as follows:
   a. The valve on the heating coil is wide open.
   b. The fresh air damper is closed and the recirculated air damper is wide open.
2. As the room temperature rises above 68°, the fresh air damper opens to the minimum position as set by the manual minimum positioning switch.
3. On a room temperature rise from 68° to 72°, the steam valve is modulated from open to closed.
4. As the temperature rises above 72°, the fresh air damper is modulated from the minimum position to 100% open for cooling.
5. On a fall in room temperature, the preceding cycle is reversed.

Note: 1. When the unit ventilator fan motor is shut down, the spring return damper motor runs to the closed position, thereby closing the fresh air damper and opening the recirculated air damper.

2. A low limit controller must be used with this type of unit ventilator. Its primary function is to protect the steam coil from freeze-up under conditions during which the valve is open slightly and the fresh air damper is open to admit freezing air. Also, the control cycle is improved by leveling out fluctuation of discharge temperature. Should the discharge temperature drop suddenly due to weather or occupancy conditions, there would ordinarily be a time lag before the thermometer felt this temperature change. As a result, there would be a period during which cold air would be discharged into the space, causing an uncomfortable drafty condition. The low limit controller limits the discharge temperature to a set minimum, thereby precluding the possibility of cold drafts and improving the control results.

3. "It must be understood that the system described in Fig. 16 cannot be used unless the heating surface used for the heating coil is recommended by the manufacturers for modulating service in tempering coil applications, because air at a temperature below freezing may enter the coil when the control valve is only part way open."

ZONE CONTROL

FOR

APARTMENT BUILDINGS, COMMERCIAL BUILDINGS AND HOMES

SECTION VI

Printed in U.S.A.

Zone Control

GENERAL APPLICATION

Zone Control may be defined as the division of a building into sections with reference to wind velocity, wind direction, solar radiation, temperature, type of occupancy, construction, and maintained temperature in such a manner that all desired temperature requirements are met in the most economical manner.

The combined effect of all four outside weather factors, which are temperature, wind direction, wind velocity, and solar radiation, determine the heat loss and consequently, the heat requirements for any building. It is obvious that that portion of a building receiving the benefits of the sun's rays should require less heat than other zones, and those zones exposed to cold wind should receive more heat than those not so affected.

A building may be split up into any number of heating zones, each of which is separately controlled. The adaptation to any building is predicated on a proper arrangement of the piping system to permit the division of the building into zones within which temperature conditions and requirements are, on an average, about the same.

Zone control is applicable to almost any type of building or heating system. The first consideration in zoning a building is the division of the building into the required number of zones which are to meet the problem in the particular application. The major factors, as enumerated in the first paragraph are: Exposure, Occupancy and Construction.

It is sometimes impossible to find proper locations for inside thermostats on zoned installations particularly where the zones are large. The Weatherstat System is well adapted for this type of job, because the Weatherstat is an outside thermostat. It reacts to all the weather conditions affecting heat losses from a building; outside temperature, wind velocity, wind direction, and solar radiation. It is not, however, subject to any local internal heat gains which may effect the operation of room type thermostats. Weatherstat Control Systems and their application are treated separately in this section.

ZONING

The following discussion covers in detail the factors which must be considered for properly zoning a building, namely Exposure and Occupancy.

Exposure

Of these three factors zoning for exposure, which includes wind direction, wind velocity, solar radiation, and temperature, is usually the most important. In the event that it is not possible to zone strictly in accordance with exposure, due to the piping or duct layouts, then a division should be made to separate those portions of the building which are subject to the most extreme conditions from those portions which are subjected to less extreme conditions. To explain this more fully, assume that a medium sized building located in the northern central portion of the United States is so arranged that the zoning can be accomplished as desired.

1. From the exposure standpoint the north space of this building is seldom subjected to solar radiation, and therefore, this portion of the building will require the most heat during the winter cycle. In order that the other parts of the building will not be overheated while this north space is receiving the required amount, it will be desirable to separate the remainder of the building from the north portion and make the north space a single zone.

2. Similarly, while the east front will receive solar radiation effects part of the time, it is not subjected to the prevailing winds, which are northwest, and therefore, should require less heat than the west space. It would, therefore, be desirable to segregate the east and west spaces into separate zones.

3. The south space will receive more sun effect than the others, and therefore, in order to permit a smaller amount of steam to be delivered to this portion of the building, it should be a zone in itself.

Where the distribution system is such that zoning into four zones cannot be accomplished, the next best arrangement would be to have the north and west spaces a single zone and the south and east spaces a separate zone. Thus, the two spaces which would be most subject to the prevailing wind would be operated to give them heat when the other parts, namely, the south and east portions of the building, did not require it.

In the larger buildings, of course, even one space of the building may have to be sub-divided into more than one zone and there are also the oddly shaped buildings where the exposure question is not so clean-cut, but the principle outlined above for sub-division on the basis of exposure should be applied as far as possible.

Occupancy

The zoning of a building on the basis of occupancy is of importance in the interest of fuel saving where various portions of the building are used for different purposes. For instance, in an industrial building where part of the building may be used as an office, higher temperature will be required in this portion of the building than will be necessary in some other portion which is used for factory purposes. Again the question of piping layout will, in many cases, determine what can be done along this line, but the ability to segregate those portions of the building that do not require high temperatures will produce a worth while steam saving.

Closely akin to the question of occupancy is the question of time in zoning. The Weatherstat System or Thermostatic Control permits the temperature to be lowered in each zone when that particular zone is unoccupied; for instance, during the night hours. This principle can be extended where portions of the building are used only at certain periods of the day or for certain days in the week.

ZONE CONTROL

Vertical Zoning

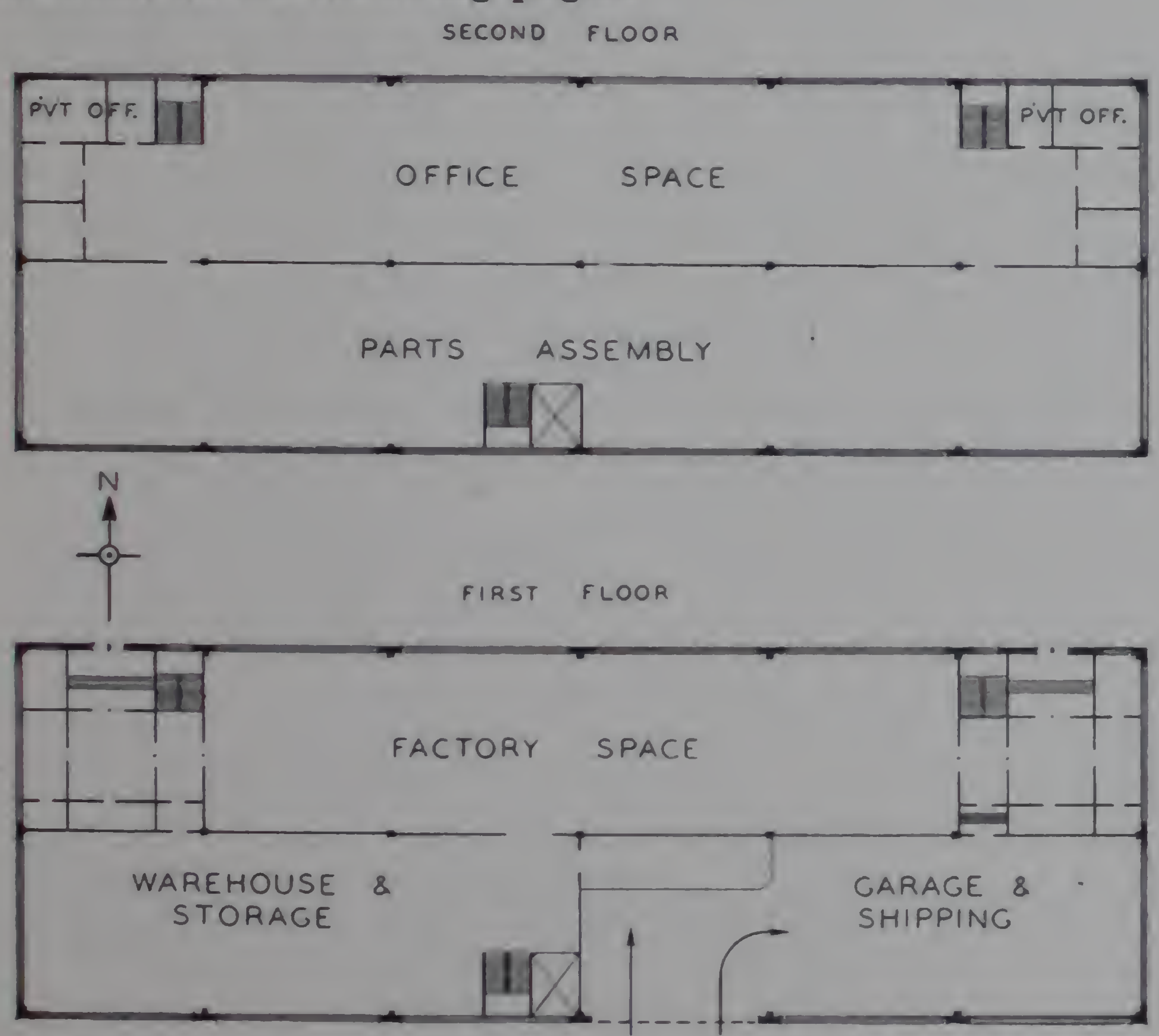
Zoning with reference to the vertical axis is one phase that has not been thoroughly analyzed. From a standpoint of economy of operation this may often be highly desirable.

When zoning with this in mind, the distribution system again becomes the limiting factor.

For example, in a building with a large central stairwell or other opening throughout its height, a pronounced stack effect is found. Thus in the case of tall buildings it becomes further necessary to arrange zones one above the other, or vertically, to compensate for this stack effect. The air, which is heated throughout the height of the building, tends to accumulate in and seek exit from the top stories of the building. This flue effect causes a reduction in normal infiltration in the upper stories and, of course, an increase in the lower stories. If this stack action were constant, correction could be made in radiator sizing and the usual considerations of exposure and occupancy need only to be given to zoning. Since, obviously, the stack effect will vary widely with outside temperature and wind effect, vertical zoning is the only satisfactory solution to proper heat distribution other than individual room control.

Typical Example

The following example provides an analysis of a typical job requiring zone control. The arrangement of control equipment is not covered in this example but is discussed in detail on the following pages.



The figure above illustrates a two-story industrial building measuring 100'x300'. The building is exposed on all sides and the long dimension faces north and south. The lower floor is divided into three parts, as follows:

1. **The north half is used for heavy factory work.**
2. **The southwest quarter is used as a store room and warehouse.**
3. **The southeast quarter has a garage and shipping platform.**

The second floor is divided to provide:

1. **Space for general and private offices in the north half.**
2. **Facilities for light assembly operations in the south half.**

The building is steam heated with direct radiation throughout the factory. A central fan air-conditioning system is used to maintain temperature and humidity conditions within the office space during both the winter heating and summer cooling cycles. Separate heating and cooling coils are provided for each of the private offices.

The application of temperature control equipment to this building involves a careful consideration of the zoning problem and since the conditions encountered are typical in whole or in part with those found in all locations, it may be considered as a basic example.

In considering each of the features involved, it is noted that:

1. In general an industrial building of the type illustrated should be zoned on the basis of occupancy rather than exposure. It is interesting to note, however, that in this particular instance zoning for occupancy provides in addition the maximum beneficial effects of an exposure layout.

2. The ground floor of the building includes a garage and shipping platform, a storage space and a section devoted to heavy manufacturing operations. The heating requirements of each of these sections differ from those of the other two and it is therefore advisable to consider their control problems separately. Temperatures in the storage space seldom need be kept at a level consistent with human comfort and the only definite requirement to be maintained is that protection be provided against freezing. This space therefore should be considered as a separate zone controlled by a single thermostat located in the storage room and connected directly to an automatic control valve placed in the steam supply line.

The garage and shipping platform likewise call for considerably less heat than is supplied to the sections where large numbers of workers are concentrated. However frequent cold blasts caused by opening of doors in the garage will necessitate heat input in excess of that required for the warehouse section. This space should therefore be treated as a separate zone and controlled independently by a thermostat and steam control valve.

Heavy factory work provides an opportunity for activity on the part of laborers which in itself will prove sufficiently stimulating to legislate against high temperatures in this location. However, precautions must be taken to maintain conditions within a reasonable comfort zone and as these levels are different from those in the garage and warehouse, individual zone control of this area is likewise suggested.

3. On the second floor are the general offices and also a section set aside for light assembly work. These areas present independent control problems. The workers in the light assembly department are seated while carrying on the various processes assigned to them and in order to provide comfortable working conditions for them, it is necessary to maintain temperatures there which are higher than those carried in other parts of the factory. This, plus the lower heat loss due to exposure, will explain the necessity of laying out this section as a separate zone.

4. Since the general office space is heated and cooled by a central fan air-conditioning system, its control cannot be interconnected with those regulating conditions in other sections of the building. Its control problem must therefore be separately considered.

5. Since each private office is provided with separate booster heating and cooling coils, provision must be made to provide for independent regulation of this equipment from the various private office spaces. Each private office would therefore become a separate zone.

Zone Control for Apartments and Commercial Buildings

for Residences Bulletin SA1759

The heating costs for apartments and commercial buildings are higher than they should be only too frequently because of the need of proper automatic control. Automatic zone control offers a means of effectively reducing wastes in the cost of heating by preventing overheating. Wasting fuel dollars often results because it is necessary to overheat in one zone in order to have the proper temperature in another zone. Zone control not only affords greater economy but adds greatly to the comfort of the occupants.

GENERAL APPLICATION

The Minneapolis-Honeywell Zone Control Systems for Apartments and Commercial Buildings may be divided broadly into those systems using inside thermostats and those using outside controllers as the primary controlling device. The latter systems bear the trade name Weatherstat. Although Weatherstats are ideally suited for apartments and commercial buildings, because of their unique operating principle, they are covered under a separate heading rather than under the type of heating systems in the pages which immediately follow.

Some of the typical systems which follow are based upon two position operation of the zone control valves while some systems are best suited for modulation of the zone valves. Generally speaking, a modulating control is more satisfactory when properly applied than is a two position control.

A two position zone valve opens fully on demand for heat from its paticular zone, thereby permitting maximum flow of the heating medium to be reached and the heating system to be "saturated" in a very short time. When the zone temperature is satisfied the valve closes, thereby shutting off fully the flow of heating medium. The modulating zone valve is typically neither fully open nor fully closed, but tends to move between these positions with a gradual action, thereby increasing or decreasing the flow of the heating medium in small increments. This latter type system is commonly referred to as a continuous flow system.

Two position control has an advantage of simplicity because the periodic "saturating" and "robbing" the heating system of heating medium usually presents no problems of distribution. Modulating control, on the other hand, requires that careful consideration be given to the matter of distribution. The typically throttled flow of heating medium may tend to "saturate" some heating units, but at the same time rob others in the same zone of their proportionate share, thereby producing uneven heating within the zone.

Two position control has a greater tendency to produce overshooting and undershooting of temperature because of the lag in the heat output and curtailment following thermostat demand for more and less heat respectively. An open-closed valve will be open a certain percentage of the time for a given heating load condition, but the more frequently the valve cycles in producing this net amount of valve opening the less will be the tendency of the zone temperature to overrun or underrun the thermostat setting. The Minneapolis-Honeywell heat actuated thermostats for inside use and the Weatherstat for external application permit two position zone control valves to be operated with optimum frequency, thus making possible results which are far superior to those of any conventional thermostat. Their use makes it possible for on-off control to approach modulating control results as nearly as it is possible to do so.

The on-off valve operation may create sudden changes in heating load should most or all of the two position zone valves open or close at approximately the same time. Thus boiler pressure for example may drop suddenly or rise to a dangerous level. If the residual boiler heat is low and there is a multiplicity of zones or if the zone system of heating utilizes only a fraction of the total boiler capacity sudden boiler pressure fluctuations are not likely to occur; any two position zone control job, however, should be carefully checked so that if necessary a reverse acting Pressuretrol may be added to operate with one or several zone valves to provide pressure relief. Frequently a program switch is added so that only one zone valve at a time can open or close with a predetermined time interval between valve operations.

The modulating or continuous flow systems of zone control do not require the added precaution against sudden changes in supply pressure as for two position systems because of their inherent tendency to increase or decrease heat input by small amounts.

There frequently arises the question of which type of zone control from a cost standpoint is best suited for a particular building. Shall it be a Weatherstat System or an inside thermostat application? Shall it be based upon modulating or two position control? To arrive at the answers to these questions the same fundamental rules of economic balance should be used as in the case of selecting any mechanical equipment that goes into a building. The type, age, and use of a building determines the standard in its class and should govern the selection of the control system. For example, a building largely used for warehousing, upon first thought, may not seem to justify any expenditure for an automatic control system. However, as frequently happens, a more thorough investigation reveals that by automatically controlling the heat at the lowered temperature permitted in this type of building, substantial fuel savings are accomplished. It is further revealed that the fully automatic nature of the control system has saved man hours and makes it a sound investment. Since the uniformity of temperature is not of paramount importance, however, a two position zone control system with rather large zones is no doubt a proper solution. If a representative thermostat location for each zone, such as is usually possible in large undivided spaces, is available inside zone thermostats will undoubtedly serve satisfactorily; otherwise a Weatherstat System should be used to avoid inside thermostat location.

If the building under consideration, however, is a modern apartment drawing rent in the higher brackets then the use of a modulating or continuous flow zone control system is almost a necessity if the tenants' comfort is to be given the proper consideration—nor is fuel economy less of a factor in a building of this type. So much importance is attached to tenant comfort by many apartment and office building owners and operators that individual radiator control valves and individual room thermostats are used throughout the building. In this instance each room, in effect, becomes a zone.

Apartment buildings, office buildings, hotels, etcetera, divided as they are into comparatively small units of space, should as a general rule, use a Weatherstat Zone Control System instead of inside thermostats as a satisfactory key thermostat location is usually impossible.

ZONE CONTROL—Heating Systems

The systems of zone control described and illustrated herein may use plain type thermostats, clock type thermostats, or a combination of both as the job may require. Any zone may by means of a clock type thermostat have its temperature automatically lowered at night and again automatically raised in the morning. The several zones may thus have separate programming based upon hours of occupancy, type of service, etcetera. Where several zones have the same program it is often more economical to provide a separate clock thermostat in one zone to serve as the master day night control for all zones. The regular plain type zone thermostats provide daytime or raised temperature setting control only while the master clock automatically assumes control for the night or standby period.

Any system of zone control may be provided with dual or day and night plain type thermostats. This arrangement further uses a remote time or program switch to switch from day to night thermostats and vice versa. Thus any zone or group of day and night zone thermostats may be programmed remotely.

STEAM HEATING SYSTEMS

Key Thermostat Method

Some buildings are so arranged that an average temperature for a given heating zone exists at a certain point in the zone. If this is the case a zone control system as shown in Figure No. 1 may be used.

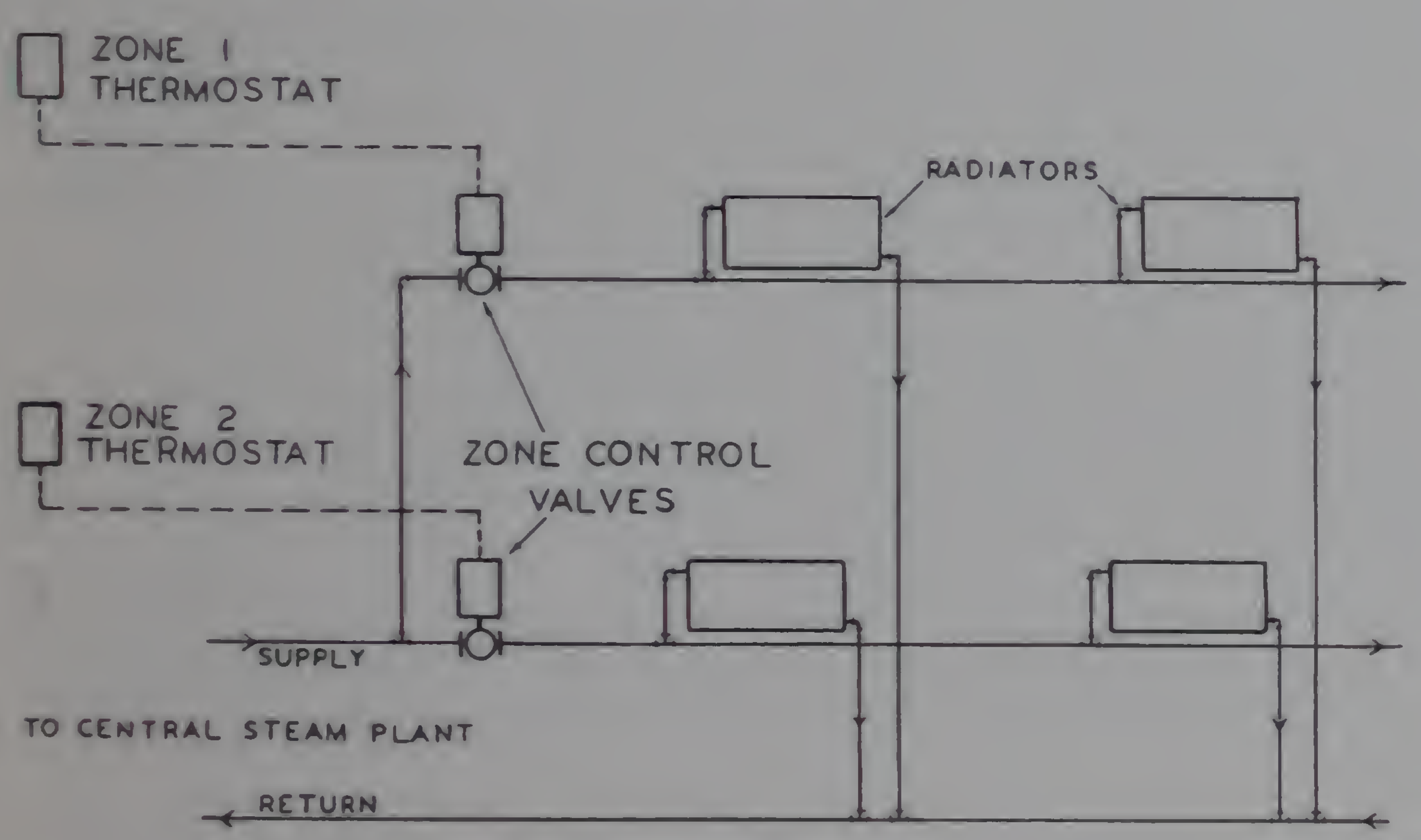


Figure 1

Here a Room Thermostat is placed in a key location in each zone where it controls the Motorized Valve in the steam line serving the radiation in the respective zone. The Thermostats maintain the zone temperatures at the desired level by opening and closing their valves.

This system usually makes use of two position, i. e. open or closed steam valves, although modulating thermostats and valves are frequently employed where care is taken to see that the steam is evenly distributed by means of proper sizing, orifices, etcetra.

Although only two zones are shown, the system may employ as many zones as required and may be pneumatic or electric as best fits the particular job.

Averaging Thermostat Method

It is usually impractical to control a large zone of heating from one inside thermostat as any one thermostat is unlikely to be representative of the temperature conditions existing in the zone during the heating period. Figure No. 2 illustrates an averaging thermostat system which is often the proper solution in designing a zone control system.

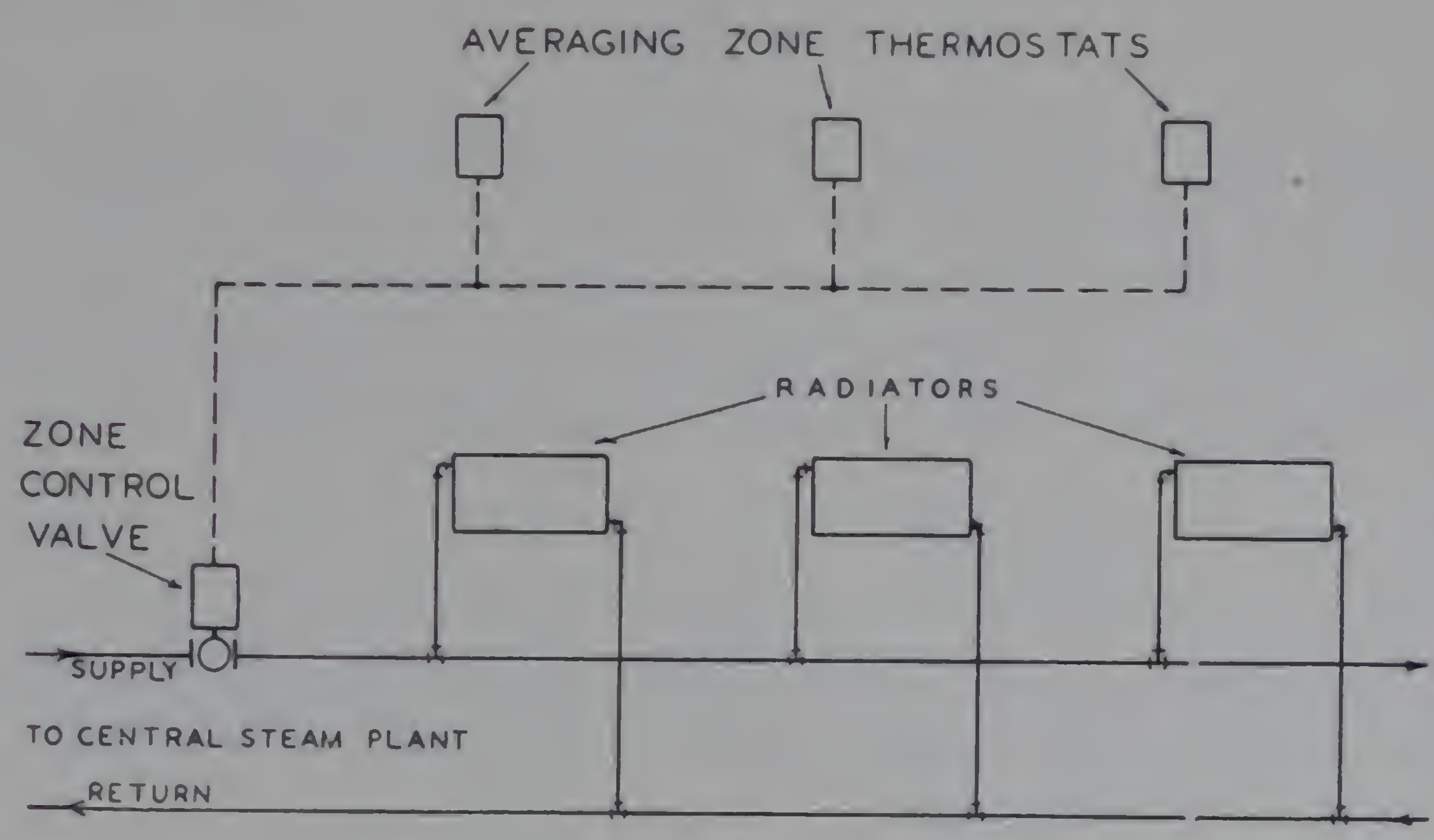


Figure 2

The several thermostats of the averaging system are connected together to control the zone valve in such a way that the average temperature of the thermostat locations is used to govern the heat supplied.

The averaging control system like the single thermostat system shown in Figure No. 1 may be had for two position control, or modulating control. If modulating control is used to provide a continuous flow system, here again radiator and possibly main orifices should be used to insure proper steam distribution throughout the zone.

As many zones like the one illustrated may be used to make up the complete averaging zone control system and either electric or pneumatic systems may be installed.

Radiator Grouping Method

In arranging a zone for a complete zone control system it is often desirable to furnish individual radiator control valves all under command of a single zone thermostat as shown in Figure No. 3.

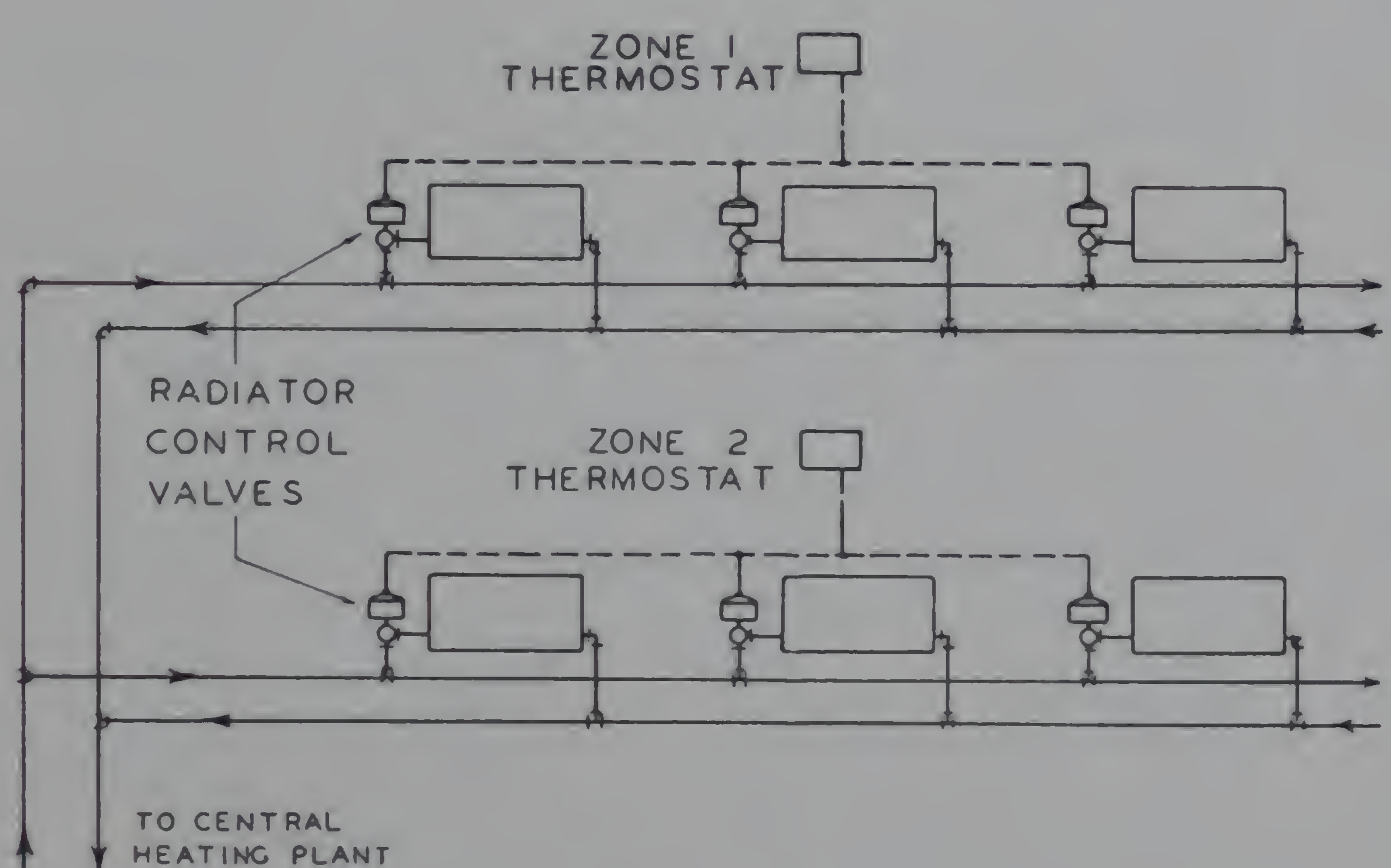


Figure 3

This arrangement frequently avoids complicated equipment and piping arrangements necessary to zone a building and is commonly used in zoning apartment buildings. Since there is no steam distribution problem involved, it is desirable to use modulating control equipment wherever possible.

Although only two zones are shown, as many similar zones should be provided as required to make up the complete automatic temperature control system.

ZONE CONTROL—Heating Systems

HOT WATER HEATING SYSTEMS

(Gravity Flow)

In zoning a gravity hot water heating system the same considerations of thermostat location, general arrangement, etcetera, should be given as for zoning a steam heating system. The schematic diagram shown in Figure No. 1 would apply to a gravity hot water installation. Here, of course, motorized valves would be selected which are designed for water service rather than steam.

(Forced Circulation)

Where the heating system is forced hot water a zone control system of the intermittent flow control type such as shown in Figure No. 1 should further provide for the control of the circulating pump. Figure No. 4 illustrates how this is accomplished.

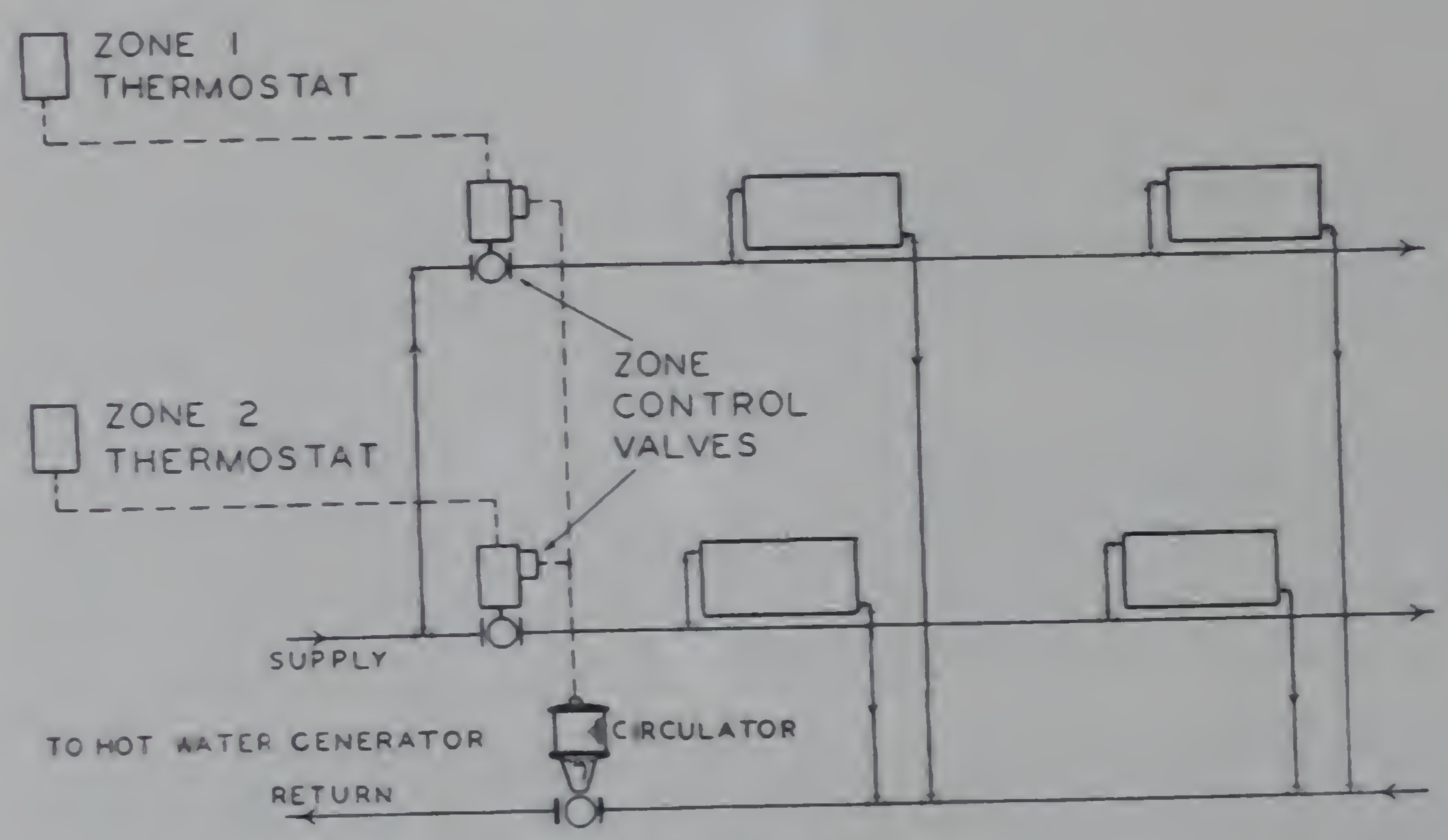


Figure 4

Here each motorized zone control valve is provided with an auxiliary switch. The auxiliary switches are connected in parallel to the circulating pump. A call for heat by any zone thermostat causes the respective zone valve to open and start the circulator. Thus when any number of zone valves are open the circulator runs. When all zones are up to temperature and all valves are closed the circulator shuts down.

Two zones are shown for illustration only. Additional zones should be added where necessary.

Figure No. 5 illustrates a system of zone control applied to a forced hot water heating system which provides modulated heat and a continuous flow of water.

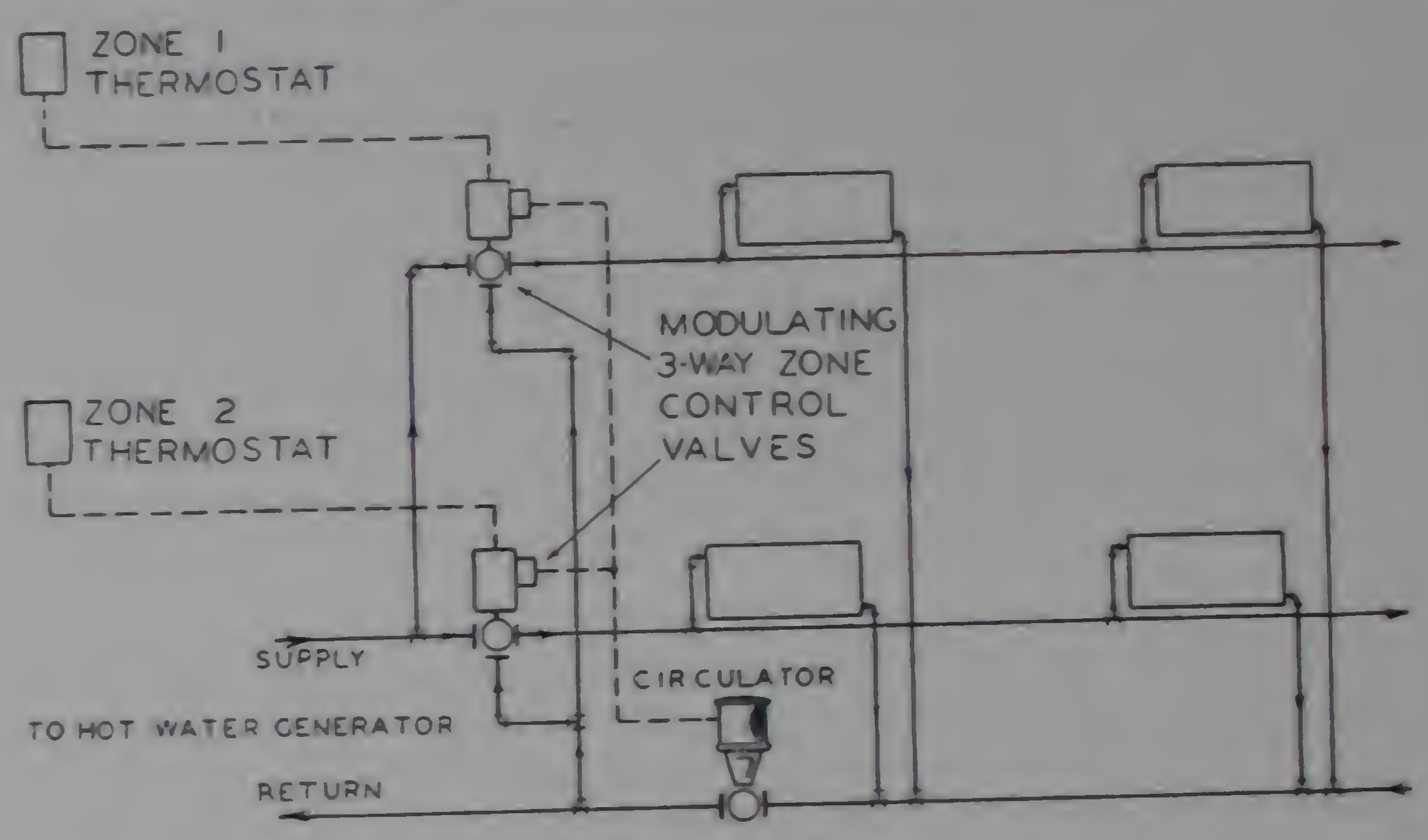


Figure 5

A modulating zone thermostat in each zone controls its respective motorized three way mixing valve installed so as to proportion the amounts of heated and bypassed water flowing to the zone. As the temperature in any zone rises to approach the desired level for which the thermostat is set, the three way mixing valve starts to close off its hot water inlet and admits proportionally more bypass water into the supply line to the zone. When the thermostat in any zone is fully satisfied all water flowing to that zone will be bypassing the heat source. Thus by varying the water temperature in this manner very close regulation of the temperature in the zones may be had. Usually it is not desirable to allow the circulator to run continuously so that each zone three way mixing valve may be provided with an auxiliary switch, as shown, to shut down the circulator when all zones are satisfied.

Two zones are shown for illustration only. Additional zones should be added where necessary.

This control arrangement is often used on indirect systems where instead of direct radiation each zone is provided with a central hot water coil. Each coil heats the air which is passed to its respective zone by means of a duct system and fan. Here the amounts of water flowing through and around the indirect heating coil are governed by the modulating zone thermostat and three way mixing valve as required to maintain the desired zone temperature.

ZONE CONTROL—Cooling Systems

The application of zone control to summer cooling systems is dependent upon the same principles as those discussed under the analysis of heating systems.

The factors effecting heat gain are similar to those effecting heat loss, and zoning must be provided if these effect different portions of the building to varying degrees.

Heating systems like those discussed above are commonly arranged with a central source of supply from which the heating medium is distributed through the entire building. Zoning during the cooling cycle is, however, more commonly accomplished by providing independent heat exchangers and fan systems for each zone.

These zone systems are each, in effect, a central fan conditioner serving a definite area. The control of these individual systems may take any one of a number of forms depending upon their size, cooling medium, and construction. Variations in these methods of control are discussed in detail under the chapter on "Control of Central Fan Cooling Systems," in Section 4.

Where multiple conditioners are combined for purposes of zoning it is frequently possible to co-ordinate many of their common functions such as night shut down, morning pickup, etc., by connecting them to a central panel board located in the engineer's office or boiler room. It is also possible to include indicating and recording equipment on this panel in order that the conditions maintained in each zone may be readily checked.

Combined zone control systems for both the summer cooling and winter heating cycles may be either:

Split Systems

In such systems summer cooling and winter ventilation are provided by the same central fan units, but the heating load is carried by direct radiation. The control sequence for such arrangements of equipment may be selected by combining the features discussed under:

1. Control of Central Fan Heating Systems (page 18 to page 32 in Section 4).
2. Control of Central Fan Cooling Systems (page 32 to page 46 in Section 4).
3. Zone Control for Steam Heating Systems (page 4 in Section 6).

Central Fan Systems

In this type of system, heating, cooling and ventilation are all provided from the same conditioner units. The control sequence will be based on the principles discussed under:

1. Control of Central Fan Heating Systems (page 18 to page 32 in Section 4).
2. Control of Central Fan Cooling Systems (page 32 to page 46 in Section 4).
3. Summer-Winter Changeover (pages 45 and 46 in Section 4).

*Weatherstat Control Systems

Extreme overheating forces tenants to open windows—but any overheating wastes fuel dollars.

The exact metering of steam by the Weatherstat makes available just the proper amount of heat to maintain comfortable conditions throughout the building. "Overshooting" and "Undershooting" of temperatures are eliminated. Fuel dollars pay only for the precise number of heat units necessary to offset the effect of the changing weather conditions to which the building is subjected.

Uneven temperatures cause the majority of complaints during the winter months. If over-heating occurs—as it frequently does since the engineer has a tendency to "play safe" and furnishes more heat than is necessary—windows are frequently opened, thus cooling the building down to undesirably low levels. In either case occupants are dissatisfied.

Desirable temperatures without "overshooting" or "undershooting" can be carried automatically at all times when the building is equipped with Weatherstat control. Tenants' complaints may be completely eliminated.

GENERAL APPLICATION

The Weatherstat is an outside type of thermostat for use in controlling temperatures in large buildings or large zones where control from an inside thermostat is impractical. It is unique in that it reacts to all weather factors which affect heat losses from a building or zone. These factors are:

1. **Outside temperature.**
2. **Wind velocity.**
3. **Wind direction.**
4. **Solar radiation.**

In designing a heating system, it is necessary to provide capacity for the most severe conditions which will be experienced in the course of the winter. These very severe conditions will be experienced only about 5% of the heating season. It follows, therefore, that full capacity of the heating plant will not be required during 95% of the winter season. In order to conserve fuel and to maintain comfortable temperatures, the operation of the heating plant must be controlled.

To control a large building or zone from an inside thermostat, it would be necessary to find a so-called "representative location" for the thermostat. It is often impossible to find such a location because local conditions—for example, variations in occupancy, lights, machine loads, etc.—influence the thermostat to such a degree that other parts of the building will be underheated or overheated, depending upon what factors are affecting the thermostat. In order to correct overheating, tenants are forced to open windows, with an accompanying waste of fuel. If parts of the building are underheated, tenants will complain.

Resultant temperature

A temperature index known as "outside resultant temperature" can be arrived at by summing up the effect of the four weather factors. For example, the heat losses from a building on a cloudy day with a 10 m.p.h. wind blowing and a thermometer reading of 15° above zero may be identical with the heat losses from the building on another day which is cloudy with no wind and which registers 0° at the thermometer. Under such conditions the outside resultant temperature the first day (15° F.) would be 0°, due to the wind effect.

Design temperature

For every combination of building and heating plant, there is some outside resultant temperature at which the heating plant must operate 100% of the time to maintain a certain comfortable inside temperature. This outside resultant temperature is known as the design temperature for the particular combination of building and heating plant in question. Every zone in a building may have an entirely different design temperature which will depend upon its radiation, construction, etc.

*Trade Mark

WEATHERSTAT SYSTEMS

Determination of heating requirements

Assume that a building with a design temperature of —10° is to be considered. Referring to the accompanying chart, select the diagonal line originating at —10° on the right hand ordinate. This diagonal line shows the relationship between the outside resultant temperature and the per cent of time during which full capacity of the heating system is needed. The chart shows that when the outside resultant temperature is 30°, full capacity of the heating plant is required only 50% of the time in order to keep the space up to the desired temperature; at 70° no heat will be required; and at —10° 100% capacity is required.

This chart can be used with any zone or building, no matter how large or small, so long as the correct design temperature can be determined, because all heat losses bear a direct relation to outside resultant temperature.

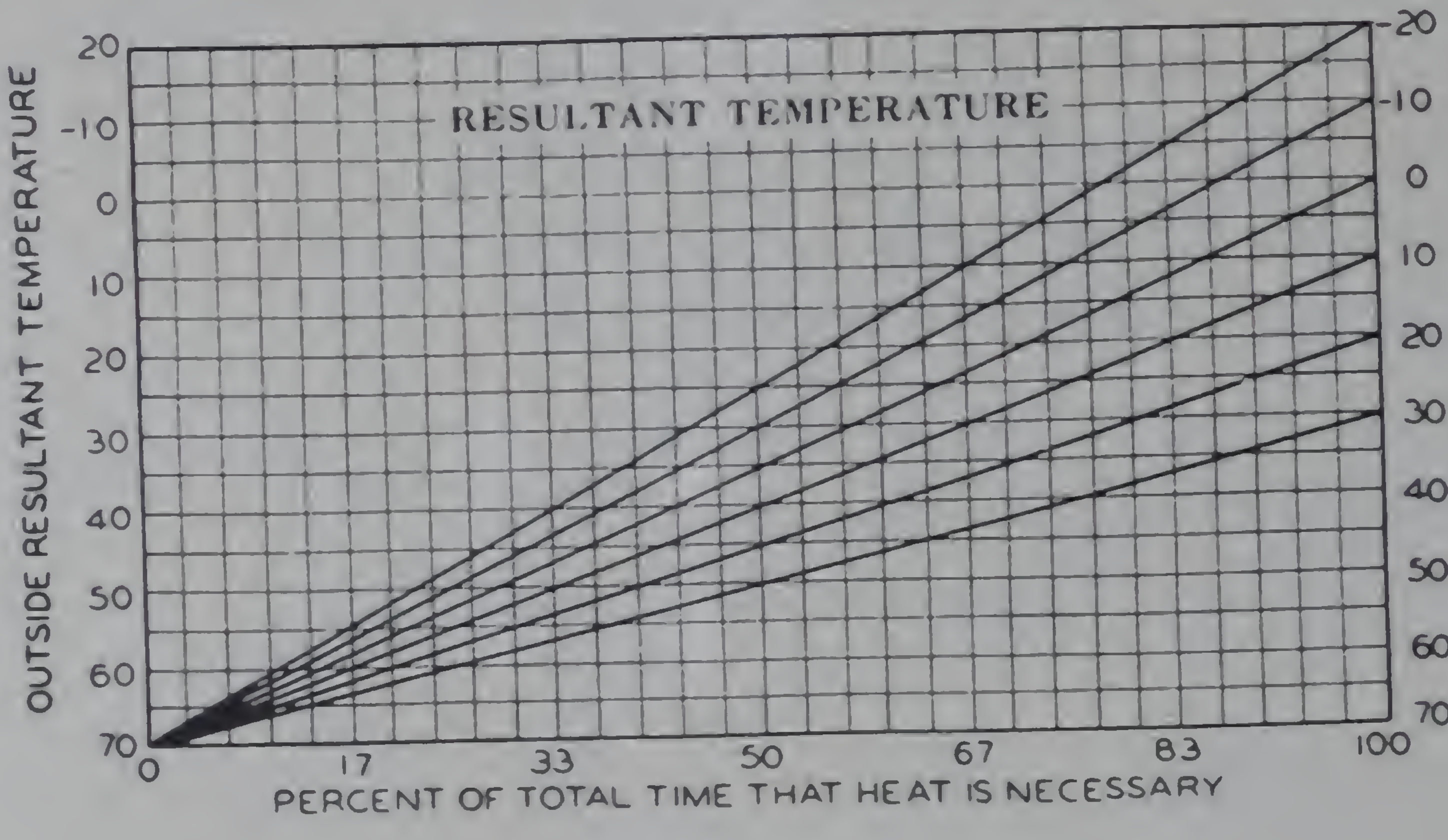


Figure 1

Weatherstat theory

Consider two buildings not similar in construction or size. The large building is heated by 50,000 sq. ft. of radiation. It is of fire-proof steel construction well insulated. The small building is heated by 2,000 sq. ft. of radiation. It is of brick and frame construction. The two buildings are dissimilar in many respects. However, they have one thing in common—they both have the same design temperature—minus 10°.

Assume that a thermostat could be located in each building controlling each heating plant.

At +70° outside each building would require no heat.

At —10° outside each building would require heat 100% of the time.

At +30° outside each building would receive heat 50% of the time.

At any outside condition both buildings would have their heating plants operating the same percentage of time.

Since this is true, it would not be necessary to have a thermostat in each building. The heating plant in the large building may be accurately controlled from the thermostat in the small building. More than one thermostat is not needed—because regardless of outside conditions, both heating plants will operate at the same relative capacity.

This is exactly what the Weatherstat does!

Mounted on the outside of the building, the Weatherstat may be considered just such a small building as that mentioned above. It contains its own thermostat and heating plant in the form of an electric heater.

The design temperature of the Weatherstat is adjustable—it can be varied to just match that of the zone or building to be controlled. If the heat source of the building and the Weatherstat heater are operated simultaneously, both at the command of the Weatherstat thermostat, exactly the correct amount of heat will be metered to the building to offset its heat losses.

The Weatherstat is in effect a miniature building.

The curves in Figs. 2, 3 and 4 (plotted time against temperature) show the temperature variations and also the length of cycles which can be expected with room thermostat control as opposed to Weatherstat control.

Although the Weatherstat gains and loses heat much faster than the building, it is adjusted to the same design temperature so that it will require heat for the same number of minutes in each hour.

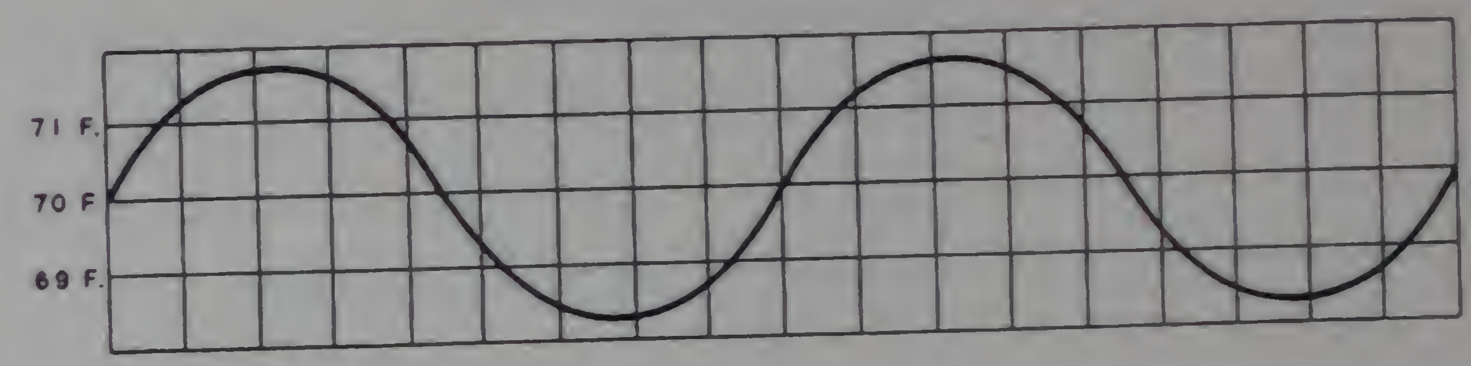


Figure 2

Fig. 2 illustrates the results if an attempt were made to control a large building or a large zone from an inside thermostat. The curve shows undesirable "overshooting" and "undershooting" of the control point, which is occasioned by the thermal lag of the building. Whenever the thermostat calls for heat, there is considerable inertia to be overcome and therefore the temperature of the building rises very slowly. When the temperature does reach the control point, the heating system has been in operation for so long that it has stored up more heat in the risers and radiation than can readily be dissipated. Therefore, the temperature continues to rise and "overshoots."

Since the temperature also drops very slowly, the result is long "on" and "off" cycles with wide temperature variation.

The Weatherstat gains and loses heat much faster than the building. Therefore, the temperature variation of the Weatherstat itself appears as shown in the chart below, Fig. 3.

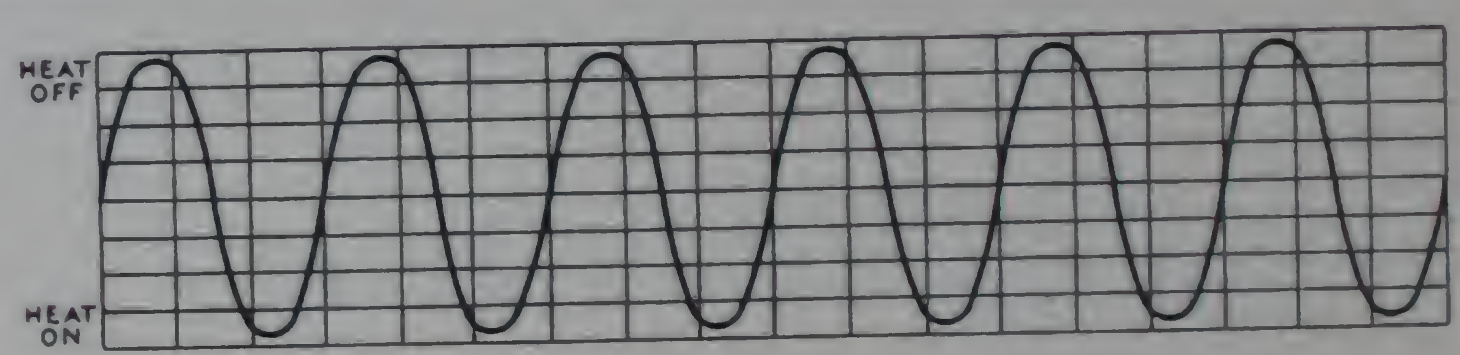


Figure 3

A building controlled by the Weatherstat has many more cycles per hour than a building under the control of an inside thermostat.

Fig. 4 shows the effect of the Weatherstat control on the building. The temperature of the building, with its slow rate of rise and fall, will not be changed perceptibly during the short time of one cycle of the Weatherstat.

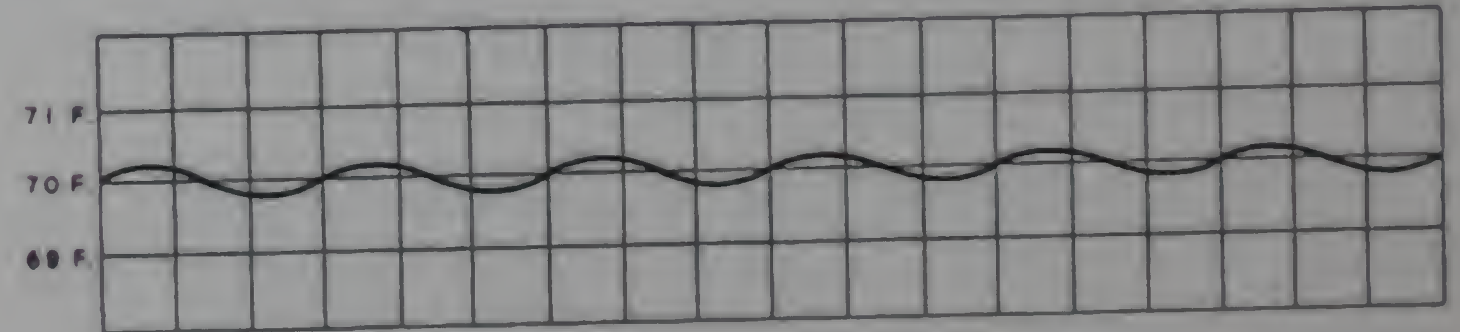


Figure 4

By shortening the "on" and "off" cycles, exactly the same amount of heat can be supplied to the zone over a certain period. The risers and radiators, however, will not tend to become cold, and very little temperature variation will occur in the building. In effect, heat will be furnished to the zone at an almost constant rate.

WEATHERSTAT SYSTEMS

TYPES OF WEATHERSTAT SYSTEMS

Weatherstats find their widest application on large buildings which cannot be controlled properly from inside thermostats. The flexibility of the Weatherstat makes it possible for the instrument to be worked into control systems for handling most of the heating systems normally found in buildings larger than single family dwellings.

Very often the Weatherstat can replace an inside thermostat for controlling directly the operation of the heating plant. This can be done with both steam and hot water.

The Weatherstat can be used for controlling the individual steam valves or hot water valves serving the various zones on larger buildings where zoning is advantageous. For the simpler heating problems, two- position or "on-off" control can be used.

The Weatherstat can be used as the primary control in a modulating control system on installations where modulating or continuous flow is considered to be advantageous. It offers many advantages over other continuous flow systems.

WEATHERSTAT DIRECT CONTROL SYSTEM

The Weatherstat Direct Control System is applicable to forced hot water, steam, or vapor heating plants fired by stoker, oil, or gas burners. It is recommended for forced hot water systems equipped with a circulator, flow valves, and a separate Aquastat to control the burner and maintain a constant boiler water temperature. Weatherstat systems can also be arranged to handle a heating system which includes facilities for providing a summer-winter supply of domestic hot water.

The Direct Control System is ideal for buildings too large to be satisfactorily controlled from an inside thermostat but small enough to be controlled as a single zone. For example, small apartment buildings, hotels, and clubs can all be heated more economically and with greater comfort under a Weatherstat Direct Control System.

This system substitutes the Weatherstat for the conventional inside thermostat to control the automatic firing device. Included in the system are the Weatherstat itself, a Control Panel housing all the necessary accessories, and a heater control to regulate the operation of the Weatherstat heater.

Figure 6 illustrates schematically the circuit of a simple direct control system. The Series 10 Weatherstat is connected to the Weatherstat panel and through the relays and the manual switch in the panel is connected directly to a Series 10 or Series 20 primary control. The primary control can be an oil burner relay, a gas valve or a stoker relay. The manual switch provides a positive "off", a continuous "on", or places the Weatherstat in control of the primary control. The standard limit controls are used with the primary control, and their selection depends upon the type of burner which is used.

Power for the Weatherstat heating element is supplied by a transformer which is controlled from a "heater control." This heater control is mounted in the supply riser so that it will react to the heat delivery to the space. When the temperature or pressure in the riser indicates that the radiators are furnishing heat to the space, the heater control closes its circuit and starts heating the Weatherstat heater element.

After the Weatherstat contacts have broken, thereby interrupting the operation of the burner, heat will continue to be supplied to the radiation for a short time depending upon the characteristics of the heating plant. The heater control is capable of sensing this condition and will continue to energize the heater element until heat is no longer being dissipated by the radiators. In this way the Weatherstat is able to measure every bit of heat which is supplied to the space.

The rheostat is connected in series with the Weatherstat heater element. The rheostat dial is calibrated for design temperature and is adjusted to match, the design temperature of the Weatherstat with that of the building which it is controling.

Figure 5

Figure 5 is a picture of the standard control panel which is a part of all direct control systems. This panel provides a central box for wiring, and includes a Weatherstat heater transformer, relays, the rheostat, the "on-off-automatic" manual switch, a power switch for interrupting the current for the entire system, and a pilot light to indicate when the heating system is turned on.

Hot Water Systems

Very satisfactory results are obtained when the Weatherstat controls directly the circulator on a forced hot water heating system. The control arangement is very similar to the one illustrated in Figure 6, except that a Series 10 relay is substituted for the Series 10 primary control. The relay in turn controls the circular motor and the primary burner control. Circulator

A low limit control must also be provided for operating the burner. This same type of system can be used for controlling systems which provide a summer-winter supply of domestic hot water.

Lowered Night Temperature

Through the addition of a Timeswitch in the panel, lowered night temperature can be provided with the Weatherstat direct control system.

At some predetermined time in the evening the time switch will turn the burner off so that the Weatherstat can no longer operate the burner. When the burner is shut off either manually or by the day-nite time switch for night shut down, the Weatherstat starts through a cooling period in the same manner as the building. These off periods are usually much longer than the off periods produced by normal cycling of the Weatherstat. The Weatherstat consequently cools to a lower level than the normal operating temperature which is approximately that of the building temperature. When the Weatherstat is once more placed on "automatic" or daytime operation, it requires an extra long "on" period to heat up to the operating daytime range. Thus the extra pickup heating required to restore the building temperature is automatically provided.

Frequently, an area under Weatherstat control may be subjected to an abnormal heat loss condition which would cause it to lose heat at a faster rate than the Weatherstat during shutdown periods. Under these circumstances the Weatherstat pick-up reserve may not be sufficient to restore the building to the normal operating level and an

WEATHERSTAT SYSTEMS

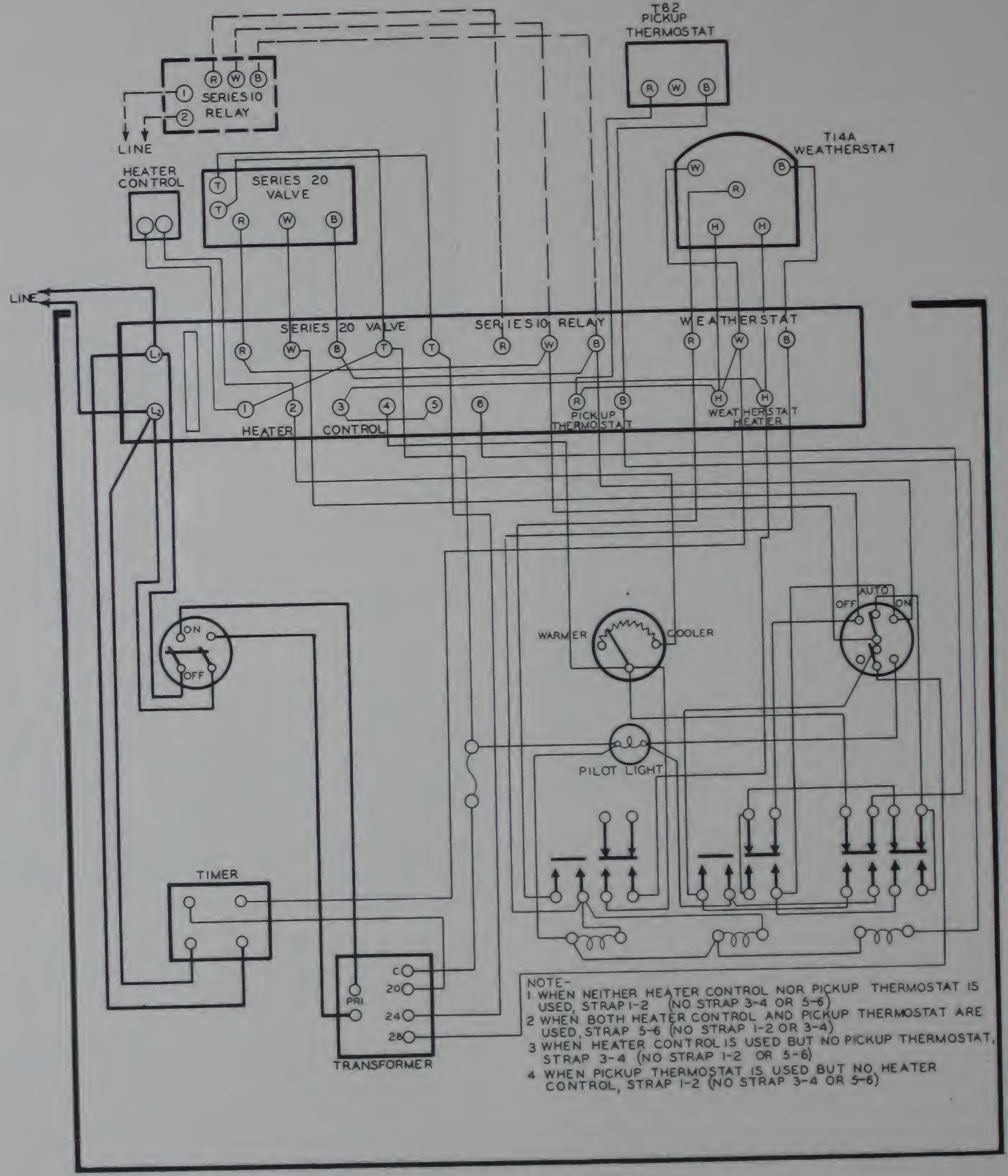


Figure 6

inside pickup thermostat should be included in the installation. When the timeswitch or manual valve switch places the control system on "automatic" or day operation following shut down, the inside pick-up thermostat takes command until a positive restoration of inside building temperature is accomplished. Then the Weatherstat takes over the controls as before.

On some installations it may be advantageous to include a night low limit thermostat so that the night temperature in the building will not drop below some pre-determined point. This can be accomplished through the use of a standard single pole single throw Snap Acting Thermostat which is wired in parallel with the Timeswitch contacts. In this way, whenever the temperature at night drops below the setting of the night low limit thermostat, the circuit to the Weatherstat will be completed, and the Weatherstat will operate the heating system until the night low limit becomes satisfied and again breaks its circuit.

WEATHERSTAT SYSTEMS

WEATHERSTAT TWO-POSITION ZONE CONTROL SYSTEM

The Weatherstat is very adaptable as a zone control system. The Weatherstat is used with a steam valve as illustrated in Figure 6. The building is zoned in accordance with the discussion on pages 2 and 3 of this section, and each zone is controlled by its own Weatherstat and steam valve system.

The same attractive control panel as is used in the direct system is furnished as a part of each zone installation. This panel includes a line switch, a Weatherstat heater rheostat, "On-off-automatic" manual switch, and a pilot light to show when the valve is open

Zone valves for the Weatherstat system are made up of three units—a motor, a linkage, and a valve body. They are of the "on"-"off" type for the two-position Weatherstat.

The Modutrol Motors used for powering Weatherstat zone valves are capacitor type motors with all of their gears and moving parts sealed in oil. Oil immersed gears insure long quiet service and eliminate the necessity for periodic lubrication.

The linkage used with M-H motorized valves includes a valve position indicator. This indicator allows the engineer to determine at any time whether a particular zone valve is closed or open. The linkage is so flexible in its design that the same linkage is used for all sizes and designs for valve bodies.

The valve bodies are furnished according to the characteristics of the service required. Single seated patterns, with self-aligning composition discs and bronze bodies, are furnished for low pressure steam service. For high pressure steam applications, semi-balanced cast iron bodies with stainless steel seats are furnished.

On those systems where lowered night temperature is desirable, a similar panel is available which also includes a Timeswitch. Both of these panels provide a convenient central wiring box and include terminals for making all the interconnections between the different pieces of equipment. One of these standardized panels is necessary for each zone.

If a Weatherstat zone valve is closed either manually or by the day-nite time switch for night shutdown, the Weatherstat starts through a cooling period in the same manner as the building. These off periods are usually much longer than the off periods produced by normal cycling of the Weatherstat. The Weatherstat consequently cools to a lower level than the normal operating temperature which is approximately that of the zone temperature. When the Weatherstat is once more placed on "automatic" or daytime operation it requires an extra long "on" period to heat up to the operating or daytime range. Thus the extra pick-up heating required to restore the zone temperature is automatically provided.

Frequently, a Weatherstat zone may be subjected to an abnormal heat loss condition which would cause it to lose heat at a faster rate than the Weatherstat during shutdown periods. Under these circumstances the Weatherstat pickup reserve may not be sufficient to restore the zone to the normal operating level and an inside pickup thermostat should be included in the installation. When the time switch or manual valve switch places the control system on "automatic" or day operation following shutdown, the inside pickup thermostat takes command until a positive restoration of inside zone temperature is accomplished. Then the Weatherstat takes over and controls as before.

MODULATING WEATHERSTAT ZONE CONTROL SYSTEM

The Modulating Weatherstat Zone Control System is used most often on large buildings, and is usually part of a zoned system, although small buildings can be treated as a single zone. Because of the fact that it is a continuous flow system, the steam supply will be throttled during mild conditions, and complete orificing of all radiators is necessary in order to insure proper distribution.

The Modulating Weatherstat Zone Control System has two outstanding advantages over other modulating steam control systems. The system includes the Weatherstat as the primary controlling unit, and therefore the system reacts to all four of the weather factors affecting heat losses from the zone: Outside temperature, wind direction, wind velocity, and solar radiation.

The Modulating Weatherstat System also provides for "on-off" or two position control during mild weather. "On-off" control during mild weather insures proper steam distribution at those times when most modulating systems have difficulty in properly distributing their heating affect, even when radiators are carefully orificed.

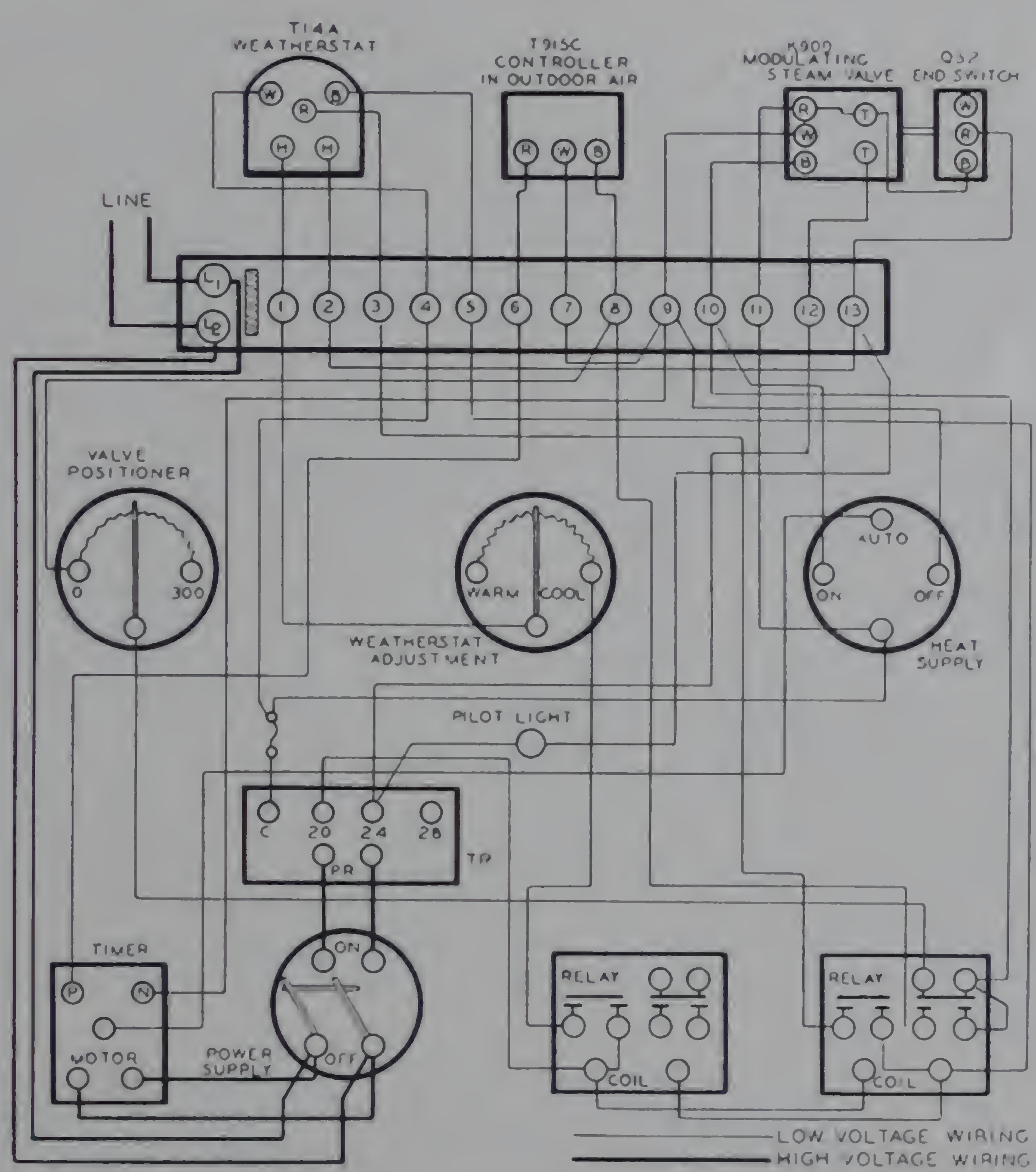


Figure 7

The Modulating Weatherstat System consists of a standard Series 10 Weatherstat, a modulating remote-bulb temperature controller with its bulb in the outdoor air, a modulating steam valve including an auxiliary switch, and a panel board which houses a series 10 relay, a valve positioning rheostat, a Weatherstat heater rheostat, a pilot light, a manual on-off automatic switch, and a transformer. One of these standardized panels is furnished for each zone.

An automatic Timeswitch for lowered night temperature can be included in the panel if the additional feature is desired.

Sectional Heating for Homes

Many home owners have taken advantage of the fact that for very little additional expense they may obtain additional comfort and economy through the use of sectional heating. Heating systems for homes should be designed with the living quarters and sleeping quarters served by different branches from the heating plant so that zone control may be easily applied. Many homes provide for a third branch in order to zone the service quarters separately. If the various zones can be arranged to have a uniform exposure as to outside conditions then the ideal design has been accomplished.

Most homes having automatic heat with thermostat control of the heating plant direct maintain necessarily a constant temperature level in all rooms throughout the day. Actually it is usually only necessary to have heat in certain parts of the home at certain times of the day. The more zones with which a home is provided the more nearly will be the exact temperature, at the right time and place. Overheating in one section in order to heat another is eliminated and fuel saving is effected if it is possible to lower the temperature in certain areas which are not in use or which may not require as high a temperature for the particular use. Sectional heating not only promotes economy but adds greatly to the comfort and well being of the occupants.

GENERAL APPLICATION

Some of the typical zone control systems which follow are the two position type while others lend themselves better to modulating control equipment. Generally speaking a modulating control system gives better performance in the uniform control of temperature than a two position control system.

A two position zone control system alternately admits maximum and minimum heat output to its zones. The modulating system is typically in neither the maximum or minimum heat delivery positions, but tends to deliver heat in amount somewhere between these positions with continuous flow and with small increments of change in output. Since two position control operates successively between maximum and zero supply pressure of the heating medium, there is usually no tendency of the heat output to favor some heating units or outlets at the expense of others. A modulating control zone may have this tendency of uneven heat distribution within a zone if proper precaution is not taken to balance delivery during periods of reduced pressure.

The tendency for uneven distribution is pronounced in modulating systems which rely on volume control of the heating medium at constant temperature. A modulating zone control system which can vary the temperature of the heating medium delivered at constant volume largely overcomes this distribution problem. A three-way zone mixing valve proportioning the flow of hot and cold water delivered to a hot water heating zone is a typical example of the latter type of system; an automatic mixing damper blending warm and cooler air quantities to a warm air heating zone is another example of a constant volume delivery or a variable delivery temperature zone control system.

A straight through zone control valve on the steam supply line to a heating zone or a control damper in the air supply duct of a warm air heating system are typical examples of the first mentioned variable volume or constant temperature zone control system.

Care should always be taken to be certain that several or all zones calling for more or less heat simultaneously do not create too sudden a change in heating demand. Thus, for example, furnace temperture or boiler pressure may build up to an excessive point should several or all zones become satisfied at the same time. This condition often requires that one or several zones be made to automatically relieve the excessive pressure or temperature through valve or damper operation from a reverse acting Pressuretrol or Airstat.

Modulating zone control systems do not have as much tendency to overshoot or undershoot the desired room temperature as do two position control systems. This is obvious when we consider that under two position control a heating unit will continue to give off stored up heat to a space after the flow of heating medium is stopped and that there will be a lag in the opposite direction when the flow of heating medium is resumed due to the initial heating of the heating units and the supply branches before the space temperature starts to rise. Modulating control on the other hand raises and lowers a heating unit or supply air temperature with gradual action, thereby reducing any tendency to overshoot or "hunt" to a minimum. The average temperature of the heating units or supply air will be the same for both modulating and two position control on otherwise identical systems for a given load condition. The temperature curve will be fluctuating in the case of the latter while it will be, practically speaking, straight line along the average in the case of modulating control.

It will be apparent, therefore, that two position control could be made to approach the results of modulating control only if the zone valves are opened and closed with sufficient frequency to produce a gradual change in heating unit or supply air temperature. Usually this is impracticable so that where job conditions make modulating control, either economically or otherwise, impossible the zone thermostats should be Minneapolis-Honeywell heat actuated type so that zone valves will be cycled with optimum frequency.

STEAM HEATING SYSTEMS

The control system shown in Figure No. 1 is designed to control a two-zone steam heating system. As many similar zones may be added as necessary.

A Room Thermostat is placed at the location in each zone where it will be subjected to the average temperature in that zone. The Thermostats maintain the temperature at the desired level by opening and closing Motorized Valves in the steam supply to their respective zones.

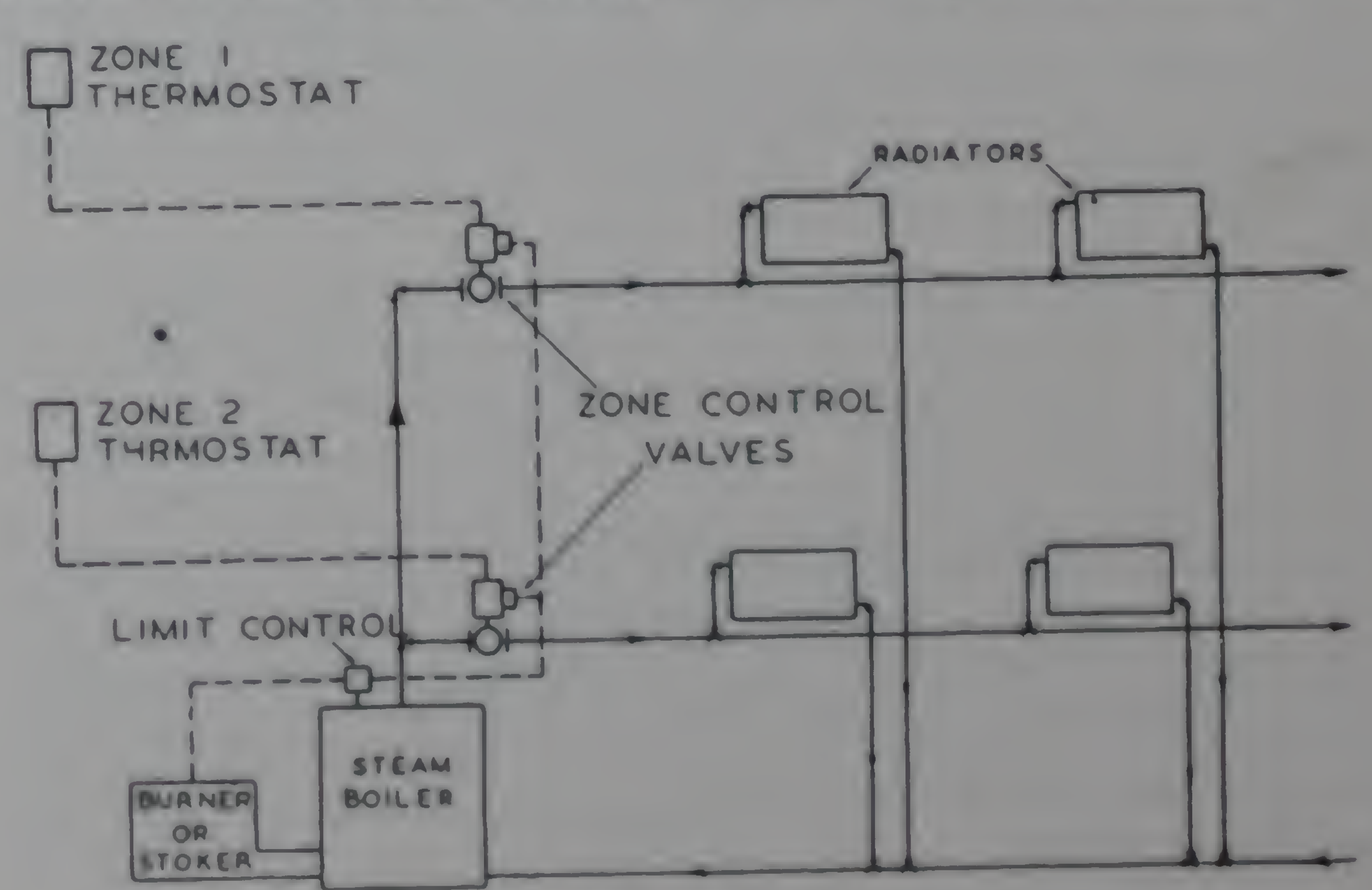


Figure 1

ZONE CONTROL—HOMES

A Lo-Water Cutoff and a Pressuretrol should be included in this system to shut off the burner in the event of low water or excessive pressure in the boiler.

A Low Limit Immersion Aquastat is frequently used to maintain the boiler water temperature close to the steaming point. This control permits more accurate regulation of the room temperatures, especially during mild weather, by reducing the delay in the generation of steam after the opening of one of the zone valves. It also provides for a minimum water temperature so that a "below the water line" heater can be used for domestic hot water.

Where zone valves are installed on systems that pull a vacuum in the returns, care should be exercised to prevent any possibility of an excessive amount of water leaving the boiler through the return lines when the zone valves close. This may be accomplished by means of automatic return traps. A Hartford return connection is recommended as a safeguard against this hazard. If return line check valves are depended upon to avoid this hazard, be sure that each separate zone return line is provided with a check valve, and not merely the single common return line to the boiler.

HOT WATER SYSTEMS

(Gravity)

The Control System shown in Figure No. 2 is a typical Zone Control arrangement for a gravity hot water heating system. As many zones like the two shown may be used as required.

The Motorized Flow Valve is installed in the hot water supply riser feeding the zone, and allows hot water to flow into the zone only when it is opened under command of the Room Thermostat.

Each motorized valve is equipped with an auxiliary switch which closes a circuit and starts the burner when the valve reaches the open position. The burner may be started by the opening of either valve, and it will continue to run only as long as either valve is open.

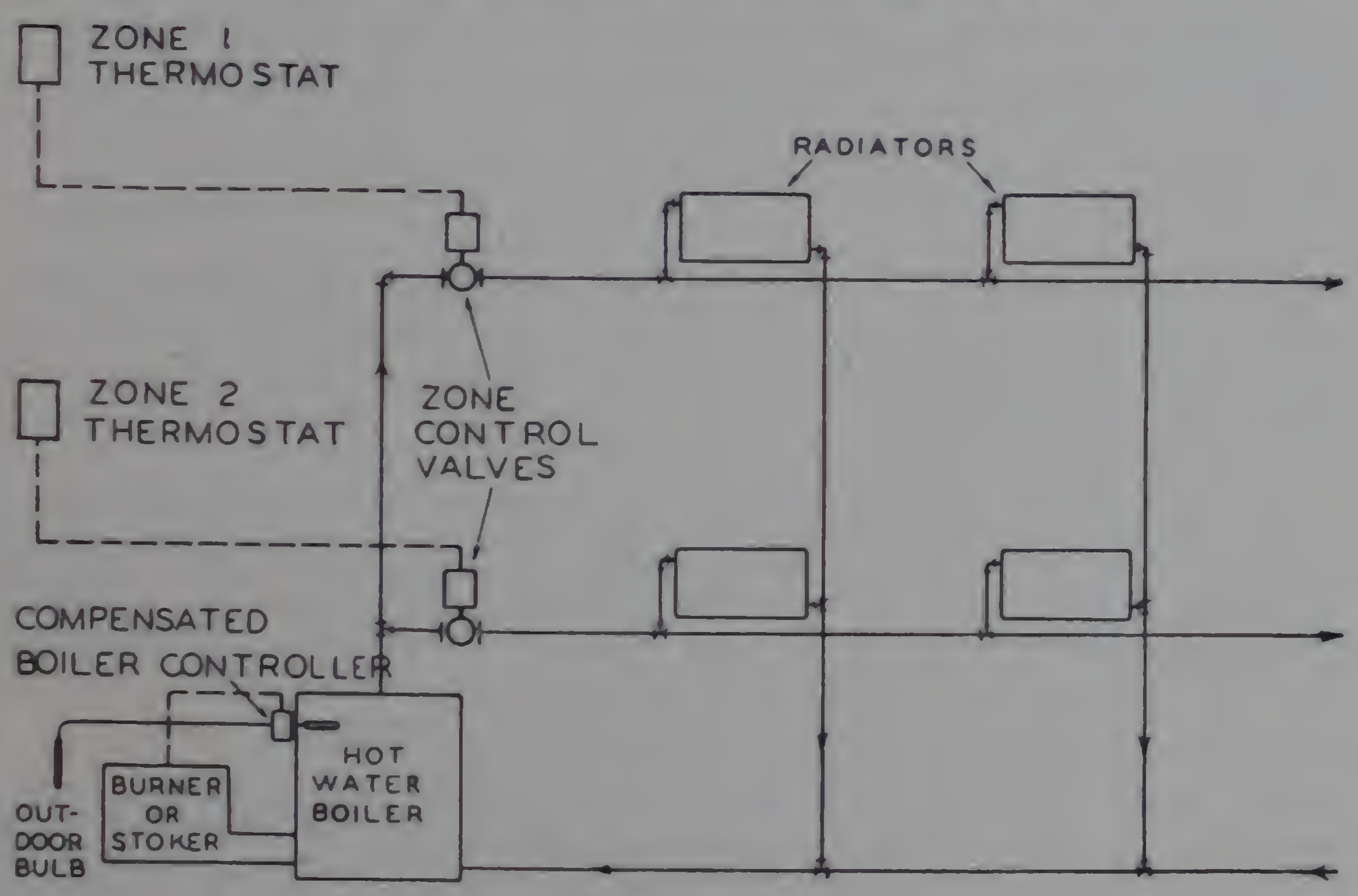


Figure 2

Lowered night temperature may be obtained in any one or more zones if desired by substituting a clock type Thermostat for the plain Thermostats shown in the illustration.

The compensated hot water controller is installed with control bulb in the boiler water and the reset bulb out of doors. As the outside temperature drops through a predetermined range the boiler control point setting is raised through a corresponding predetermined range. Thus the boiler water temperature is maintained at just the right level to carry the heating load measured by the outdoor bulb. If the burner is to be used for furnishing domestic hot water the year around a boiler aquastat may be used to maintain a constant boiler temperature in place of the compensated boiler controller.

(Forced Flow)

A typical forced hot water zone control system is shown in Figure No. 3. This system is similar to the control system illustrated for the gravity hot water control system in Figure No. 2 except that auxiliary switches are furnished with each motorized Flow Valve and wired in parallel to the circulating pump. As many zones as required like the two shown may be used.

As long as any one of the zone control valves are open the circulator will run. When all thermostats are satisfied, i. e. all zone valves closed, the circulator will shut down.

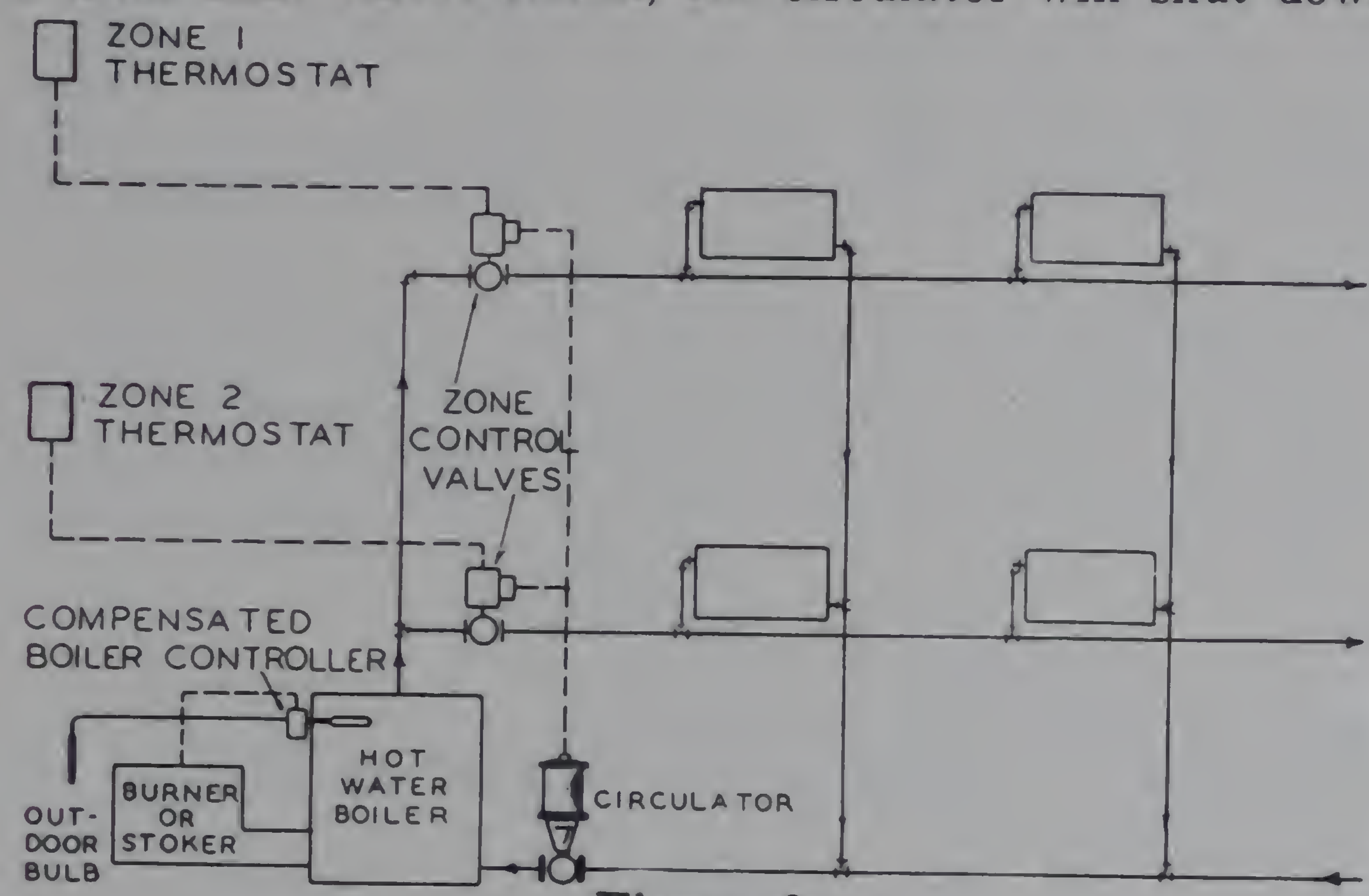


Figure 3

Boiler water temperature is varied through some predetermined range with relation to the outside temperature by means of the compensated boiler controller as described for the gravity hot water system. If the burner is to be used for furnishing domestic hot water the year around a boiler aquastat may be used to maintain a constant boiler temperature in place of the compensated boiler controller.

Figure No. 4 illustrates an excellent system of zone control for a forced hot water heating system. Such a system has the advantage of a continuous flow of water at variable temperature during heating demand.

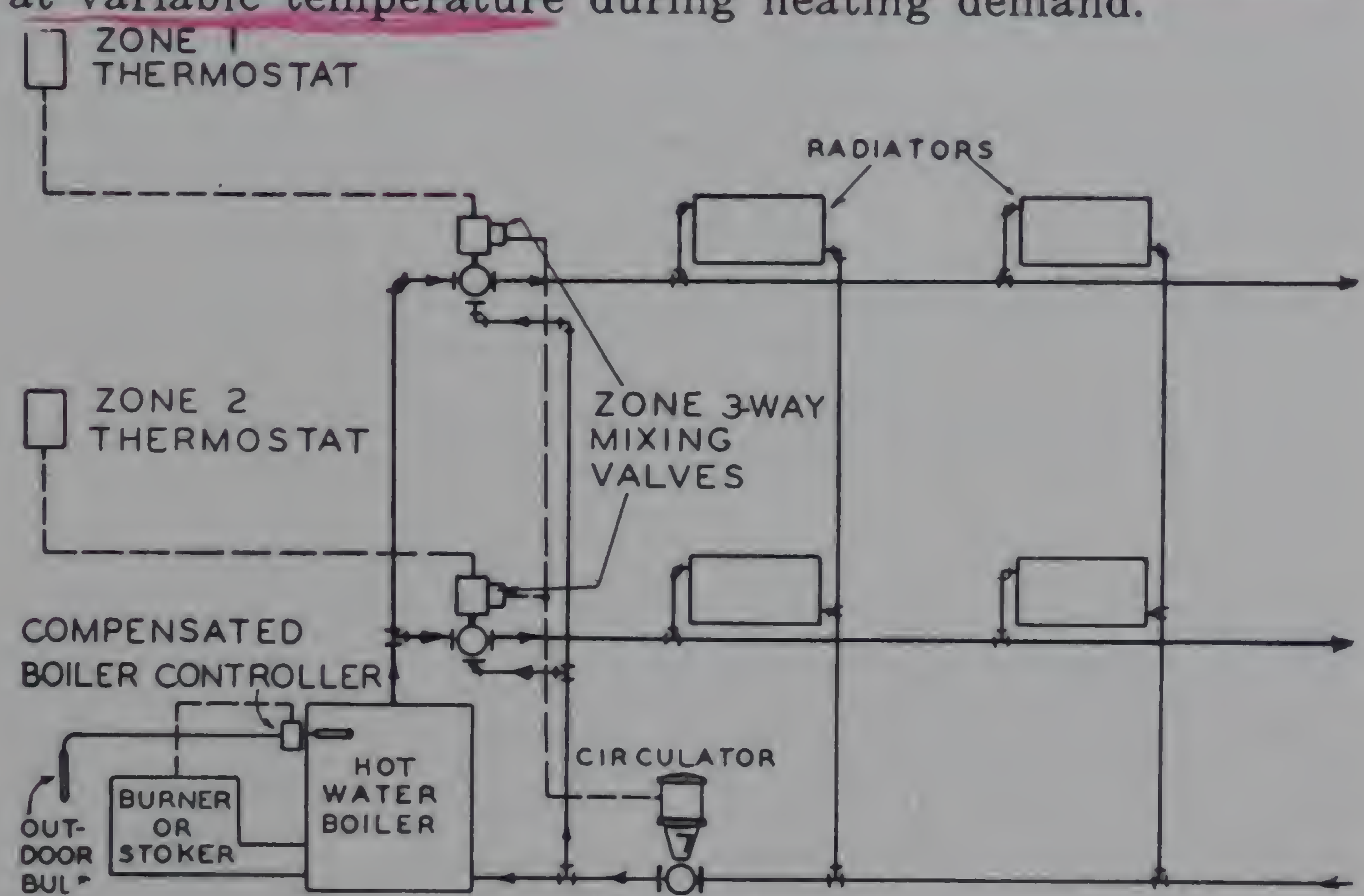


Figure 4

A modulating zone thermostat operates a proportioning three-way mixing valve with inlets from the boiler supply line and from the boiler bypass or return line. The outlet is connected to the hot water supply line to the zone. Thus under demand from the zone thermostat the modulating three-way valve proportions the relative amounts of water flowing through and around the boiler as required to deliver water at the proper temperature necessary to maintain the desired zone temperature.

Zone three-way mixing valves are provided with auxiliary switches connected in parallel to the circulator. When all zones temperatures are satisfied, that is, when all water is bypassing the boiler the circulator will shut down.

Primary control of the boiler may be the same as for the previous systems.

ZONE CONTROL—HOMES

FORCED WARM AIR HEATING SYSTEMS

(a) Volume Damper Zone Control

Figure No. 5 shows a simple zone control system for regulating room temperature where a warm air heating system is used.

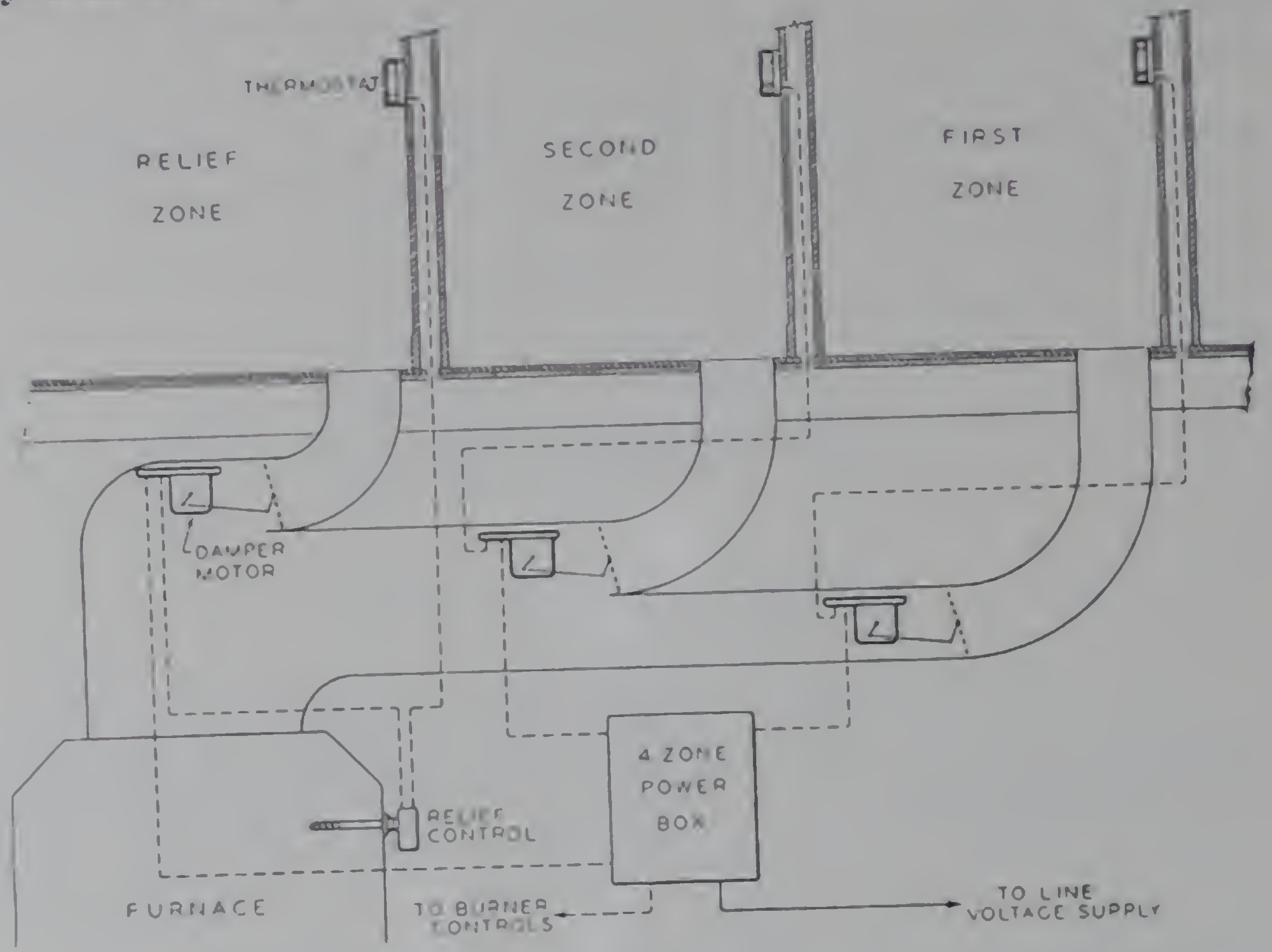


Figure 5

Controls required for the first zone consist of a room thermostat, zone damper motor with operating linkage, and a power box to house the motor transformers and terminal block for wiring connections. The power box is equipped to serve four zones. Additional zones require only a thermostat and damper motor unless there are more than four zones to be controlled.

The operation of the system is such that when any zone requires heat, the motorized damper in that zone supply duct is opened at the command of the thermostat and at the same time an auxiliary switch on the damper motor is closed completing the circuit, through the power box, to the burner and blower. The primary controls for the burner are not shown. However, the zone controls will work satisfactorily with any of the standard primary control systems.

A Safety High Limit Control should always be used to prevent excessive temperature in the bonnet.

In a zone control system of this type it is usually desirable to make one of the zones a "relief zone".

During normal operation of the heating system it frequently happens that all zone dampers close at approximately the same time. With circulation completely shut off, the bonnet temperature may build up to an excessive point unless one of the zone dampers is opened to relieve the overheated air. The relief zone controls consist of the usual thermostat and damper motor and in addition, a reverse acting limit control in the furnace bonnet. This control opens the zone damper, even though the zone thermostat is not calling for heat, if the bonnet temperature exceeds a predetermined high limit. When this occurs the high limit control wired into the primary control circuit, being set at a lower point, prevents the burner from operating even though the zone damper is open.

(b) Direct Mixing Damper Zone Control

The volume damper control system described above, while effective in controlling temperatures, has certain fundamental limitations. For example, if a group of people were collected in the "living zone" the body heat and lights would tend to reduce the heating requirements and the volume damper would close. This occurs when this particular zone would most require the air motion of an open damper in order to remove smoke and odors.

Further if only one zone damper of a multiple zone system is open all the available air tends to be pushed by the fan into that zone which may result in drafts and an objectionable amount of noise.

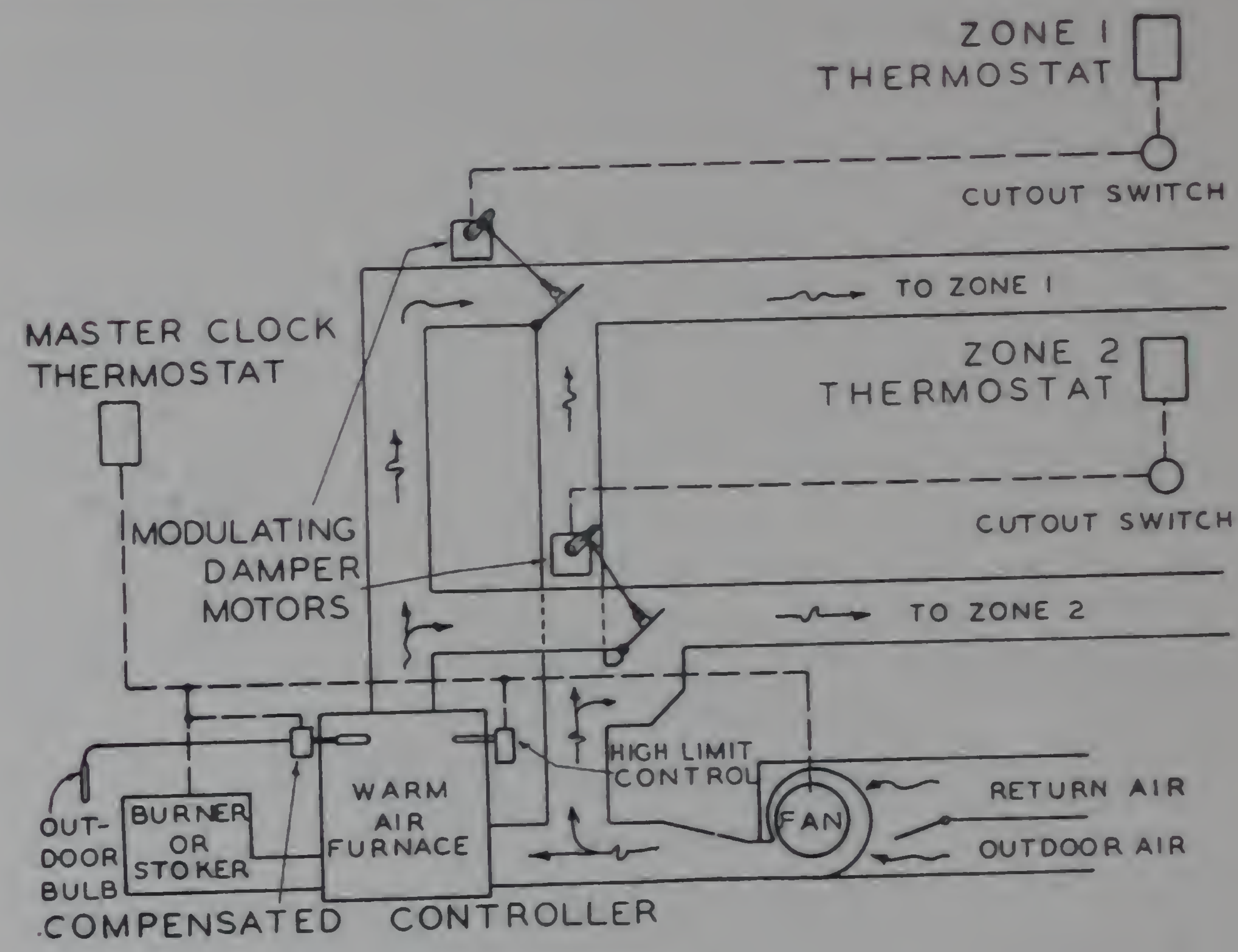


Figure 6

Figure No. 6 illustrates a system of zone control applied to a forced warm air heating plant which overcomes the limitations of the volume damper control system by varying the heat input to the zones by means of changing the temperature of a constant volume of delivered air. Any number of zones similar to the two illustrated may be used to make up the complete control system. The system operates as follows:

A modulating thermostat in each zone controls a motor operated mixing damper with graduate action. In this manner warm air and bypass air are mixed in the exact proportion and delivered to the zone at just the right temperature to offset the heat loss from the zone.

The compensated bonnet temperature controller determines the temperature of the air leaving the furnace according to the outdoor temperature and operates the burner accordingly.

A clock type thermostat may be used as a master control to shut off the burner and fan at night and automatically place them in operation in the morning. Should the temperature drop to the lowered standby temperature setting during the night the burner and fan will operate only as needed to maintain the lower temperature.

Cut out switches in each zone permit shutting off the heat to any zone but not the air circulation. Individual outlet dampers should be installed where it is desirable to shut off air circulation manually.

A reverse acting high limit control should be installed to start the fan in the event of excessively high bonnet temperature thereby dissipating excess heat which may otherwise damage the furnace.

(c) Indirect Mixing Damper Zone Control

Figure No. 7 illustrates a system of zoned forced warm air heating which operates in the same manner as the system shown in Figure No. 6 except that the heated air is furnished by an indirect heating coil and hot water or steam boiler.

The boiler control is a Pressuretrol or an Aquastat for steam or hot water respectively and operates the burner to maintain a predetermined pressure or boiler water temperature.

ZONE CONTROL—HOMES

A master clock thermostat is used to operate the fan and burner only during the night stand-by period as in the foregoing system. Any number of zones similar to the two illustrated may be used to make up the complete control system.

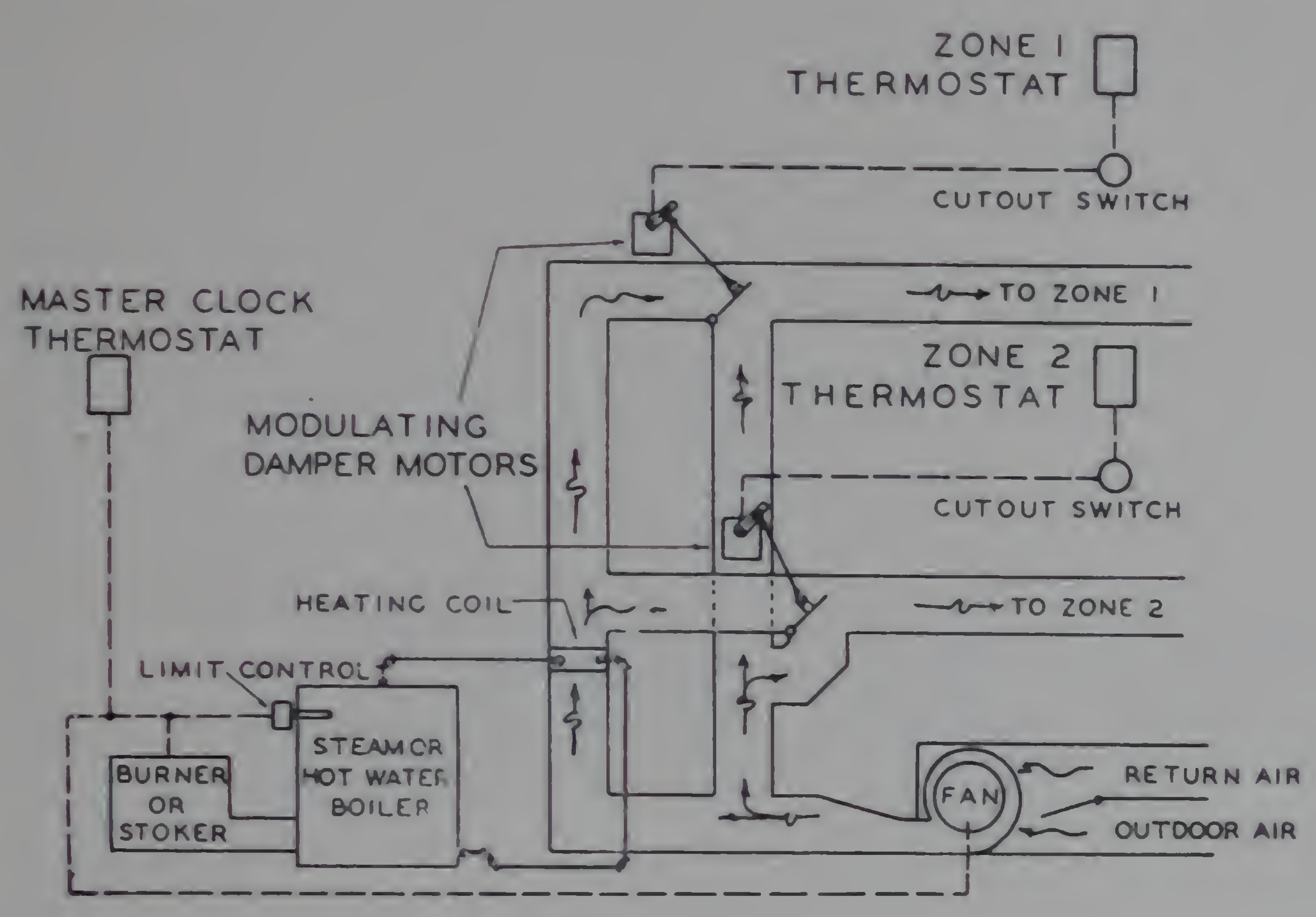


Figure 7

The warm air heating zone control systems described above, it will be seen, will provide modulated heat delivery only as long as the air circulating fans are on. If the fan of any of these systems is operated intermittently then ventilation, that is air motion and outdoor air supply, as well as heat supply, becomes intermittent also and much of the advantage of this type of system is lost.

The practice in commercial and public buildings is to operate fans of heating and ventilating systems continuously and the results have proven satisfactory. These systems, of course, are designed for constant fan operation so that they will deliver warm air during heating periods or unheated air during ventilating or cooling periods with equal satisfaction. If a forced warm air heating plant has been designed for intermittent fan operation so that air is circulated only while heated, smaller ducts and higher air velocities are permissible without producing drafts. Obviously such a system could not be placed on constant fan operation without redesigning and rebuilding. Careful thought would have to be given to the volume, velocity and temperature of the air delivered—also the method of air delivery and diffusion—so that the discomforts of a poorly designed system are avoided.

It is recommended, therefore, that full advantage be taken of the possibilities of the continuous fan zoned forced warm air heating system by designing so that low temperature air may be delivered during periods when no heat or cooling is required without objectionable drafts. Such a system (1) provides an uninterrupted supply of outdoor air, (2) prevents cold air stratification at the floor, (3) produces more uniformly comfortable temperatures and (4) provides continuous positive pressure which retards heat loss and aids air diffusion.

MASTER CLOCK CONTROL

The systems of zone control described and illustrated herein may use plain type thermostats, clock type thermostats, or a combination of both as the job may require. Any zone may by means of a clock type thermostat have its temperature automatically lowered at night and again automatically raised in the morning. The several zones may thus have separate programming based upon hours of occupancy, type of service, etcetera. Where several zones have the same program it is often more economical to provide a separate clock thermostat in one zone to serve as the master day night control for all zones. The regular plain type zone thermostats provide daytime or raised temperature setting control only while the master clock automatically assumes control for the night or stand-by period.

Any system of zone control may be provided with dual or day and night plain type thermostats. This arrangement further uses a remote time or program switch to switch from day to night thermostats and vice versa. Thus any zone or group of day and night zone thermostats may be programmed remotely.

BURNER CONTROL

A system of zone control produces a variable load upon the boiler or furnace, whichever is used to furnish heat. This load may vary quite gradually because of a modulating zone control system or because of the multiplicity of two position control zones. On the other hand, a system consisting of only several two position zones is likely to produce sudden and large demands for change in boiler or furnace heat output.

It is desirable to maintain a constant boiler or furnace temperature independent of the zone control system so that heat will be available in the proper amount when required. Obviously the best results are obtained if the boiler heat input is modulated. Modulating burner control allows for a variable heat input which may balance out any load condition imposed by the zone control system.

The storage capacity of a furnace or boiler is an important consideration in the matter of selecting the burner control. If the heating plant has very little storage capacity it would be difficult to maintain a constant heating plant temperature under widely varying load demands from a system of zone control, with on-off or high-low burner control. The burner would cycle between 100% and minimum input in an attempt to balance a typical intermediate load condition produced by the zone control. The result would be too frequent burner operations causing loss of combustion efficiency and excessive wear on the equipment.

Short cycling of the burner may be substantially reduced if the boiler or furnace has comparatively large heat storage capacity. A larger storage capacity, however, may introduce the problem of creating excessive build-up in temperature due to rather sudden call for reduction in heat output by the zone control as discussed previously.

Since modulating burner control is more flexible in its application than on-off control it is particularly recommended on heating plants used with a system of zone control.

TYPICAL SPECIFICATIONS

SECTION VII

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Typical Specifications

The following sample specifications have been written and arranged so that a complete Temperature Control Specification can be prepared with a minimum of effort. The wording of many of the sections can be identical from job to job. The only changes ordinarily necessary are the **Sequence of Control** and the **Scope** of the temperature control work.

The specifications are divided into three divisions, the first covering pneumatic control, the second covering electric equipment and the third describes "Sequences of Control" for both pneumatic and electric systems. For combined electric and pneumatic installations, suitable paragraphs from both sets of sample specifications can be selected and combined.

A complete specification will include the following:

Scope—The Scope will be varied to fit the sequence and mechanical equipment of each job.

Service and Guarantee — In general the paragraphs as shown will be satisfactory. Occasionally it may be necessary to vary the clauses for special jobs.

Air Piping — Should be included in any pneumatic, or combined electric-pneumatic specification.

Electric Wiring — Clauses covering **Electric Wiring** for pneumatic jobs will differ slightly from those used in electric control specifications. A proper paragraph should be included in any specification.

Installation of Valves and Dampers—The clauses covering valve and damper installation can usually be used as shown.

Drawings and Layouts—Occasionally the **Drawings and Layout** paragraphs will not be satisfactory as written and will have to be revised.

Control Instruments—The items listed under this heading will be different for electric and pneumatic work. Only those items which are to be used on the job should be included.

Sequence of Control — The sequence of control must of course be written to fit each individual job. Several samples covering typical sequences for various types of jobs are included to be used as patterns. The "Sequence of Control" as shown for the Weatherstat, Unit Heater, and Zone Control Systems include specifications on the equipment to be used so that no separate "Control Instrument" paragraphs are necessary.

AUTOMATIC TEMPERATURE CONTROL SPECIFICATIONS

(Typical Pneumatic Specifications)

Scope

The sub-contractor under this heading shall furnish all labor, materials, equipment and services necessary for the proper installation of a system of automatic temperature control.

Temperature control equipment shall be manufactured by Minneapolis-Honeywell Regulator Company or equal approved by the engineer.

This specification is intended to cover equipment for the automatic temperature and humidity control of:

Sample #1 (Varies with each job)

A—Main conditioned air supply fan with wetted coil washer, silica jell units, and mixing dampers for three (3) zones together with reheater coils.

B—Three (3) zone booster fans.

C—Direct radiation control.

Sample #2

A—Room and auditorium unit ventilator.

B—Direct radiation in rooms and halls.

C—Exhaust dampers.

Service and Guarantee

The control system herein specified shall be free from defects in workmanship and material under normal use and service. If within twelve (12) months from date of acceptance by the engineer any of the equipment herein described is proved to be defective in workmanship or material it will be replaced or repaired free of charge.

The contractor shall, after completion of the original test of the installation and acceptance by the engineer, provide any service incidental to the proper performance of the temperature control system under guarantees outlined above for the period of one (1) year.

After completion of the installation the automatic control contractor shall regulate and adjust all thermostats, control valves, motors, and other equipment provided under his contract. He shall place them in complete operating condition subject to the approval of the engineer.

Air Piping

Compressed air piping throughout shall be of galvanized steel pipe or seamless copper tubing, as installation conditions require. It shall be concealed wherever possible, properly supported, and installed in a neat and workmanlike manner throughout.

Suitable drip-legs and drains shall be installed at all necessary points in order to prevent condensation pockets.

The entire piping system shall be tested by placing it under 30 lbs. pressure for 24 hours. The pressure drop during this period shall not exceed 10 lbs.

Electric Wiring

All wiring in connection with the temperature control system shall be furnished by the electrical contractor as included under the electrical specifications.

Installation of Valves and Dampers

All automatic control valves shall be furnished by the temperature control manufacturer and installed under his supervision by the Heating Contractor. All automatic control dampers shall be furnished by the temperature control manufacturer, and installed under his supervision by the Sheet Metal Contractor.

TYPICAL SPECIFICATIONS

Drawings and Layouts

Upon completion of the work, the contractor shall provide diagrammatic layouts of the automatic control systems specified herein. Layouts shall show all control equipment, and the function of each item shall be indicated for the different seasons.

Temperature Control Contractor shall submit to the engineer for approval, a shop drawing of the entire control system before starting work.

Control Instruments

1. **Room Thermostats**—All room thermostats shall be of the graduate type capable of positioning valves or dampers in intermediate positions. Wherever positive-acting equipment is required, it shall be so stated in the body of the specifications. Thermotsats shall be of the non-bleed type so that no air shall be used except when a valve or damper is being moved from one position to another. All thermostats shall be equipped with a vapor-tension type of sensitive element, adjustable differential mechanism, and shall be capable of operating on a change of plus-or-minus 1° F. at the thermostat location. Where required, thermostats with special characteristics shall be furnished. Thermostats shall be finished as required, and shall be equipped with red reading thermometer and lock-type adjustments.

2. **Insertion Thermostats** — All insertion thermostats shall be similar in design to Room-type instruments except they shall be equipped with remote bulb sensitive elements connected to the instrument by not less than five feet of capilliary tubing. They shall have either external or lock-type adjustments, visible scales, and shall be provided with necessary gauges to indicate branch and main line pressures.

3. **Thermometers**—Remote bulb type red reading thermometers shall be furnished for each insertion thermostat location and the bulbs mounted adjacent to the bulb of the insertion thermostat. Thermometers shall have a range of minus 20 to 180° Fahrenheit. There shall be not less than 4 feet of capilliary tubing connecting the thermometer bulb to the thermometer case and the head of the thermometer shall be adjustable for easy reading.

4. **Humid-U-Stats**—All room-type Humid-U-Stats shall be similar in design and appearance to the room thermostats. They shall be actuated by a human hair element, have lock-type adjustments and temperature compensation. Insertion-type Humid-U-Stats shall be equipped with necessary gauges to indicate the main and branch line pressures.

5. **Damper and Valve Motors**

Option #1—Damper motors and valves shall be either normally open or normally closed, as specified, to provide the proper sequence of operation. They shall be of ample capacity to handle the required load under all conditions.

Option #2—Damper motors and valves shall be either normally open or normally closed, as specified, to provide the proper sequence of operation. The damper motor power units shall be composition bellows with low reversal loss. They shall have ample capacity to handle the required load under all conditions.

Coil valves shall be equipped with characterized Vee-port throttling guides, and a positive positioning device. Valves three inches in size and smaller shall be powered with composition bellows motors and shall have replaceable composition valve discs.

Valves and damper motors shall be as manufactured by Minneapolis-Honeywell or approved equal.

6. **Relays and Miscellaneous Items**—Necessary relays of the positive and gradual-acting type shall be furnished and installed as required for the successful operation of the system.

All switches shall be of the lever-indicating type, with indicating plates designating the function of each switch.

Satisfactory moisture condenser shall be provided of either the air-cooled or water-cooled type with trap, as approved by the engineer.

7. **Static Pressure Regulator**—The static pressure regulator shall have an adjustable range of at least 0 to 2″ water column and an adjustable differential range of .15″ to .75″ water column. The unit shall be sensitive to minute changes in pressure.

8. **Positive Positioning Devices**—All automatic control valves and damper motors for the fan systems shall be equipped with non-leaking type of positive positioning device, which shall make available the full power of the diaphragm motor in both directions so as to produce the exact position of valve or damper demanded by the controller regardless of external forces, such as air velocity, pressure, friction, etc. They shall be adjustable for sequence operation when required.

The positive-positioning device must react to both controller branch-line pressure and valve or damper position. It shall be the Gradutrol Relay as manufactured by the Minneapolis-Honeywell Regulator Company or approved equal.

9. **Dampers**—Dampers shall be of the louvre-type with black enamel finish equipped with brass bearings (or ball bearings) to permit free operation. Blades shall be not more than 10″ in width nor less than 16 gauge, and frame shall be of welded channel iron. Dampers with either dimension under 18″ may have strap iron frames.

10. **Volume Dampers** (Vol-U-Trol Dampers)

The Volume Control Dampers shall be specially curved double blade dampers hinged at the top and bottom, and capable of maintaining a constant air velocity through the outlet grills at 25% through 100% capacity when a constant static pressure is maintained in the supply ducts. They shall be Vol-U-Trol Dampers as manufactured by Minneapolis-Honeywell or approved equal.

11. **Air Compressor**—Furnish and install where indicated on the plans an air compressor which shall be operated by an electric motor of not less than — H.P and an air

TYPICAL SPECIFICATIONS

delivery of not less than — cubic feet per minute. Compressor shall be equipped with — gallon tank, pressure reducing valve, filters, gauges and automatic starter.

Sequence of Control

(Varies with the job. Samples will be found toward the rear of this section).

AUTOMATIC TEMPERATURE CONTROL SPECIFICATIONS

(Typical Electric Specifications)

Scope

The sub-contractor under this heading shall furnish all labor, materials, equipment and services necessary for the proper installation of a system of automatic temperature control.

Temperature control equipment shall be manufactured by Minneapolis-Honeywell Regulator Company or equal approved by the engineer.

This specification is intended to cover equipment for the automatic temperature and humidity control of:

Sample #1 (Varies with each job)

A—Main conditioned air supply fan with wetted coil washer, silica jell units, and mixing dampers for three (3) zones together with reheater coils.

B—Three (3) zone booster fans.

C—Direct radiation control.

Sample #2

A—Room and auditorium unit ventilators.

B—Direct radiation in rooms and halls.

C—Exhaust dampers.

Service and Guarantee

The control system herein specified shall be free from defects in workmanship and material under normal use and service. If within twelve (12) months from date of acceptance by the engineer any of the equipment herein described is proved to be defective in workmanship or material it will be replaced or repaired free of charge.

The contractor shall, after completion of the original test of the installation and acceptance by the engineer, provide any service incidental to the proper performance of the temperature control system under guarantees outlined above for the period of one (1) year.

After completion of the installation the automatic control contractor shall regulate and adjust all thermostats, control valves, motors, and other equipment provided under his contract. He shall place them in complete operating condition subject to the approval of the engineer.

Electric Wiring

All line voltage wiring for the control system shall be in accordance with the specifications under the electrical section and shall comply with the National Electrical Code. Low voltage wiring shall be installed in conduit (lead covered cable, or exposed).

Installation of Valves and Dampers

All automatic control valves shall be furnished by the temperature control manufacturer and installed under his supervision by the Heating Contractor. All automatic control dampers shall be furnished by the temperature control manufacturer, and installed under his supervision by the Sheet Metal Contractor.

Drawings and Layouts

Upon completion of the work, contractor shall provide diagrammatic layouts of the automatic control systems specified herein. Layouts shall show all control equipment, and the function of each item shall be indicated for the different seasons.

Temperature Control Contractor shall submit to the engineer for approval, a shop drawing of the entire control system before starting work.

Control Instruments

1. **Room Thermostats** — All Room Thermostats shall be of the potentiometer modulating type unless otherwise specified. They shall have vapor filled temperature elements, and shall be furnished with red reading thermometers. Two position thermostats may be either vapor or bi-metal actuated with either mercury switch or open contacts.

Thermostats shall all be furnished with lock type adjustments and shall be finished as approved by the architect.

2. **Insertion Thermostats** — Insertion Thermostats shall have vapor filled flexible elements not less than five feet in length. They shall be potentiometer modulating type controllers unless otherwise specified. Two-position controllers shall be of the mercury switch or open contact type. They shall have visible scales with lock-type adjustments.

3. **Humidity Controllers**—All Humidity Controllers shall include human hair elements and lock type adjustments. They shall have an adjustable range of no less than 20% to 80% R.H. and a minimum differential of 2% R.H.

4. **Damper Motors**—All power units shall be capacitor type with oil immersed gear trains. They shall be the modulating type unless otherwise specified. They shall have ample capacity to handle the required load under all conditions.

5. **Motorized Valves**—Motorized valves shall have capacitor type power units with oil immersed gear trains. The valve linkage shall have a valve lift adjustment and an indicator to show the valve position. Valve bodies under three inches in size shall be bronze with renewable composition discs and Vee-port guides. Valves larger than three inches shall have cast iron bodies, characterized Vee-port guides, and bronze trim.

All valves shall provide modulating action unless otherwise specified.

TYPICAL SPECIFICATIONS

6. **Automatic Radiator Valves** — Radiator valves shall have shaded pole induction type power units, renewable composition discs, and packless seal construction. They shall be angle, straight-thru offset, or straight-thru non-offset patterns as required. They shall be provided with a means for manual operation in case of power failure.

7. **Relays and Switches** — All necessary relays shall be installed as required for the successful operation of the system.

All switches shall include suitable indicating plates.

8. **Dampers**—Dampers shall be of the louvre-type with black enamel finish equipped with brass bearings (or ball bearings) to permit free operation. Blades shall be not more than 10" in width or less than 16 gauge, and frame shall be of welded channel iron. Dampers with either dimension under 18" may have strap iron frames.

9. **Volume Control Dampers**—Volume Dampers shall be specially curved double blade dampers hinged at the top and bottom capable of maintaining a constant air velocity through the outlet grills at 25% through 100% capacity when a constant static pressure is maintained in the supply ducts. They shall be Vol-U-Trol Dampers as manufactured by Minneapolis-Honeywell or approved equal.

Sequence of Control

Varies with the job. Samples of various sequences follow.

SEQUENCE OF CONTROL

Schoolhouse Control

1. Split System (M-H-R No. 2)

   Room thermostats and radiator valves shall be installed as indicated on the plans for the control of direct radiation in corridors and toilets. Room thermostats, unit ventilator control equipment, and radiator valves on direct radiation shall be installed in class rooms as indicated on the plans, to provide the following sequence. When the room temperature is below the setting of the thermostat, the coil and radiator valves shall be wide open and the fresh air damper closed. As the room temperature rises the fresh air damper shall go to a predetermined minimum open position and the radiator valve shall close. On a continued rise the valve shall gradually move to a closed position. The fresh air damper shall remain in the minimum open position until the unit valve is closed. On a further rise in temperature the fresh air damper shall move to an open position to provide fresh air for cooling. During the periods when the unit is providing a ventilating function only, an air stream controller located above the coil shall operate the unit valve and fresh air damper to maintain predetermined minimum discharge temperature.

2. Unit Ventilator Control Sequence.

   Room thermostats and radiator valves shall be installed as indicated on the plans for the control of direct radiation in corridors and toilets. Room thermostats and unit ventilator control equipment for all class room unit ventilators shall be installed as shown on the plans to provide the following sequence. When the room temperature is below the setting of the thermostat the coil valve shall be in a wide open position and the intake dampers positioned to use 100% recirculated air. As the room temperature rises the radiator valve shall first close. On an additional rise in room temperature the fresh air damper shall start to admit fresh air, moving toward the 100% fresh air position as the room temperature continues to rise. When the intake dampers have reached a position corresponding to the use of 75% fresh air the unit coil valve shall start to close and shall assume the tight closed position shortly after the mixing damper has repositioned itself to use 100% fresh air. At times when the unit is serving a ventilating function only, an air stream controller located below the unit just above the fan discharge shall reposition the intake damper to maintain a constant temperature of air entering the steam coil.

Air Conditioning Systems

(Sequence of Control)

The two samples of **Sequence of Control** below, describe two typical control systems shown on pages 18 thru 44 in Section IV. Similar sequences can be readily worked up from the description of the other standard control systems.

1. Heating Control System.

   The system shall provide for manual adjustment of the outdoor air damper to furnish any desired minimum amount of fresh air whenever the fan is running. It shall further provide for automatically increasing the quantity of fresh air whenever the temperature in the space rises above the normal control range of the return air controller. The return air and fresh air dampers shall be cross-connected and operated in reverse.

   A return air controller shall operate the modulating valve on the steam coil and shall be connected into the fresh air control system to indicate the need for additional fresh air for cooling. A low limit controller in the discharge duct shall be capable of controlling the steam valve to prevent the discharge air from dropping below 65°.

   A humidity controller shall control a solenoid water valve on the water sprays to regulate humidity.

2. Cooling Control System.

   The system shall provide manual adjustment of the outdoor air damper to furnish any desired minimum amount of fresh air when fan is running. It shall also provide for opening the outdoor air damper wide when the temperature of the outdoor air is low enough to provide cooling. The return air and outdoor air dampers shall be cross-connected and positioned by a single motor which closes the outdoor air damper and opens the return air when the fan is not running.

TYPICAL SPECIFICATIONS

The system shall include a step controller controlled by a modulating type room thermostat. The step controller shall operate by-pass or unloader valves on the refrigeration machine in several stages to automatically reduce the cooling capacity. The system shall be Minneapolis-Honeywell or approved equal.

Weatherstat Systems
(Sequence of Control)

1. Direct Control System
An outside controller, containing a temperature sensitive element and heating element, so that the instrument is responsive to outside temperature, wind velocity, and solar radiation shall control the burner directly.

The burner shall be turned off and on automatically as required to maintain the desired indoor temperature.

A control panel shall be installed and shall include (a) an "on"-"off"—"automatic" switch with which to manually control the burner if desired, (b) a rheostat with which to adapt the control level of the Weatherstat to job conditions by regulating the rate of flow of electric current to the heater element and (c) an ammeter to indicate the flow of current to the Weatherstat heater.

The system shall be the Minneapolis-Honeywell Weatherstat System or approved equal.

Note: The above specification applies to steam or gravity hot water heating systems. A forced circulation hot water system is controlled similarly except the Weatherstat operates the circulating pump, instead of the burner. Primary controls should be specified under boiler and burner.

Alternate—The system shall include an automatic time switch to lower the temperature at night and return it to the day level at a predetermined time in the morning.

2. Two-Position Zone Control
Each zone shall be furnished with a complete control system consisting of an outside controller, a control panel and a zone valve which will automatically vary the steam supply as outdoor conditions change and which will completely shut off the steam at 65° F. outdoor temperature.

Each outside controller shall be located at its respective zone and shall include a temperature sensitive element and heating element so that the controller will be sensitive to outside temperature, wind direction, wind velocity, and solar radiation. It shall operate a two-position motorized zone valve controlling the steam supply to its zone.

A control panel shall be furnished for each zone and shall be located in the engineer's room (or boiler room). It shall contain all auxiliary control equipment including a manual "on-off-automatic" control switch and a pilot light to indicate control valve position. The system shall be the Minneapolis-Honeywell Weatherstat system or approved equal.

Alternate—Each system shall include an automatic time switch to lower the temperature at night and return it to the day level at a predetermined time in the morning.

3. Modulating Zone Control
Each zone shall be furnished with a complete control system including a modulating zone valve, a control panel, and an outside controller. The temperature control contractor shall furnish any other control equipment required for the proper operation of the control system.

Each outside controller shall be located at its respective zone and shall include a temperature sensitive element and heating element so that the controller will be responsive to outside temperature, wind direction, wind velocity, and solar radiation. A modulating motorized zone valve shall be furnished for each zone.

A control panel shall be furnished for each zone and shall be located in the engineer's room (or boiler room). It shall contain all auxiliary control equipment including a manual "on-off-automatic" control switch, and a pilot light to indicate valve position.

The system shall provide a continuous, variable steam flow except under light load conditions. When a predetermined minimum or smaller load condition is reached the control shall automatically operate the normally modulating valve in an "on"—"off" manner between the closed and minimum open positions. When the load once more increases beyond the minimum condition the control valve shall once more operate in a modulating manner between the minimum and full load positions.

The temperature control contractor shall provide an orifice plate for each radiator which shall be installed by the heating contractor.

Alternate—The system shall include an automatic time switch to lower the temperature at night and return it to the day level at a predetermined time in the morning.

Zone Control
(Sequence of Control)

1. Two-Position Control
Each zone shall be furnished with a two-position motorized valve and two-position heat leveling type thermostat. The thermostats shall have means for locking the setting and the finish shall be approved by the architect.

Thermostats shall be clock type, and shall provide a mechanical resetting of the control point to provide lowered night temperature and automatic return to day levels in the morning.

The zone valves shall (insert "Motorized Valve" specification or "Automatic Radiator Valve" specification from page 4 or 5).

TYPICAL SPECIFICATIONS

2. Averaging Zone Control
Each steam heating zone shall be controlled by two (or more) graduate acting thermostats connected together in such a manner that the graduate acting zone valve will be positioned according to the average of the temperatures at the two (or more) thermostats. The temperature control contractor shall provide an orifice plate for each radiator which shall be installed by the heating contractor.

3. Forced Hot Water Mixing Valve Control
A control system shall be installed for each zone which shall vary the water temperature with graduate action as required to maintain the desired zone temperature.

Each zone shall be furnished with a modulating motorized three-way mixing valve and thermostat. Motorized valves shall be installed so that hot water from the boiler is mixed with return water and discharged from a common outlet to the main zone supply line. The modulating zone thermostat shall thus proportion the amount of hot and return line water flowing to the zone.

Each motorized valve shall be provided with an auxiliary switch which shall keep the circulating pump in operation while any hot water flow is demanded. When all zone control mixing valves reach the bypass position the circulator shall shut down.

Alternate—The system shall include a time switch to interrupt the circulator operation at night and to start it up automatically in the morning. The control system shall automatically bring the temperature up to the day level.

UNIT HEATER CONTROL

Pneumatic Modulating

Each unit heater (or group of unit heaters) shall be controlled by a pneumatic system consisting of a Graduate non-leak type thermostat operating a pneumatic coil valve installed in the steam supply line to the unit heater(s). The thermostat shall have a range of 60 to 85 degrees and the coil valve shall be equipped with a Vee-port sleeve and a positive positioning device for the proper modulation of the steam.

A pneumatic electric switch connected to the thermostat branch line shall be capable of stopping the unit fan(s) when the thermostat is not calling for heat and the valve is closed. A manual "On-Off-Automatic" switch shall be installed so that the fan(s) may be operated continuously, shut off, or operated automatically.

The air supply to the control system shall be taken from the main air compressor system and passed through a reducing station consisting of a pressure regulator set at 15 lbs., an oil filter, a pressure gauge on the high pressure side and a pressure gauge on the low pressure side. Only one reducing station is necessary for all thermostats unless it is more convenient to use more than one station.

OPTIONAL—A pressure control shall be connected to the steam supply line and connected in the electric circuit so that the fan(s) will not run when there is no steam pressure in the main except at the command of the manual switch in its "on" position.

Electric Modulating

Each unit heater (or group of unit heaters) shall be controlled by an electric system consisting of a potentiometer type thermostat operating a proportioning electric coil valve installed in the steam supply line to the unit heater(s). The thermostat shall have a range of 63 to 87 degrees and the coil valve shall be equipped with a V-port sleeve for proper modulation of the flow of steam.

An auxiliary switch on the coil valve shall be capable of stopping the unit fan(s) when the thermostat is not calling for heat and the valve is closed. A manual "On-Off-Automatic" switch shall be installed so that the fan(s) may be operated continuously, shut off, or operated automatically.

OPTIONAL—A pressure control shall be connected to the steam supply line and connected in the electric circuit so that the fan(s) will not run when there is no steam pressure in the main except at the command of the manual switch in its "On" position.

Electric Two-Position

Each unit heater (or group of unit heaters) shall be controlled by an electric system consisting of an "On-Off" thermostat which will start the unit fan(s) when heat is required. The thermostat shall have a range of 40 to 80 degrees.

A manual "On-Off-Automatic" switch shall be installed so that the fan(s) may be shut off, operated continuously, or automatically.

OPTIONAL—A pressure control shall be connected to the steam supply line and connected in the electric circuit so that the fan(s) will not run when there is no steam in the main except at the command of the manual switch in its "On" position.

ENGINEERING DATA

SECTION VIII

Engineering Data

The following pages include charts, tables, and ratings which are commonly used in the analysis of heating, ventilating, and air conditioning problems in general.

Too much emphasis cannot be laid upon the fact that the greatest limitations influencing the operation of the control system are the operating characteristics and capacities of the equipment with which it is used.

A careful analysis of all parts of a heating, ventilating, and air conditioning installation will make it possible to select a control sequence which will insure an efficient and economical program of operation.

In this data section we have attempted to include information which may be generally used in making calculations of capacities. By keeping this material in a convenient location and referring to it frequently, it will be possible for you to derive the maximum benefits that automatic control make possible.

In addition to general data the following pages also include specific information on Minneapolis-Honeywell control units which is not included in other parts of the catalog.

GENERAL ENGINEERING DATA

DEGREE DAYS

The number of degree days per day is the difference between 65° F. and the daily average temperature when the average temperature is less than 65° F.

The daily average temperature is the average of the maximum and minimum temperatures recorded during a day. It is **not** the average of all the hourly readings taken during the day. For example, if the highest recorded temperature within a day at a given location is 74° F. and the lowest temperature is 46°, the daily average temperature will be $(74° + 46°) \div 2 = 60°$. Therefore, the number of degree days for that day at that particular location will be $65° - 60° = 5$ degree days.

The following table gives the number of degree days in a Normal heating season. The monthly mean temperature used is the average of monthly mean temperatures for as many as fifty years, and usually at least twenty-five years.

It is usually more satisfactory to predict fuel consumption on this table than to rely on tables calculated from daily weather data compiled during the last few years.

	REPRINTED FROM DEGREE DAY HANDBOOK BY STROCK & HOTCHKISS													HEATING DATA			COOLING DATA	
	Total	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Days in Normal Heating Season	Design Temp.	Average Temp.	Design Dry Bulb	Design Wet Bulb
Atlanta	2890	682	557	388	132	....	....	....	....	....	96	396	639	201	10	50.6	91	75
Baltimore	4533	955	843	701	348	22	....	....	....	....	223	567	874	232	5	45.5	93	76
Boston	6045	1150	1042	908	570	245	....	....	....	48	363	695	1026	273	0	42.9	88	73
Buffalo	6822	1240	1156	1032	675	335	12	....	....	75	419	774	1104	283	—5	40.9	83	72
Charlotte	....	....	....	....	....	....	....	....	....	....	....	....	....	206	10	49.8	..	..
Chicago	6290	1262	1095	911	549	248	....	....	....	3	353	756	1113	257	—10	40.5	95	75
Dallas	2256	617	493	267	9	....	....	....	....	....	....	303	567	181	10	52.5	99	76
Des Moines	6384	1392	1173	890	441	118	....	....	....	....	357	798	1215	251	—15	39.6	92	74
Denver	5874	1079	918	800	534	267	....	....	....	72	428	759	1017	274	—20	43.6	90	64
Detroit	6490	1252	1134	973	573	226	....	....	....	42	400	777	1113	268	0	40.8	93	73
Duluth	9480	1727	1473	1277	810	524	198	....	37	261	620	1060	1491	365	—25	39	..	..
Hartford	6036	1159	1100	887	531	202	....	....	....	48	344	705	1060	272	—5	42.8	..	..
Indianapolis	5298	1128	969	756	384	59	....	....	....	....	298	687	1017	242	—5	43.1	90	73
Kansas City	4852	1094	958	676	303	12	....	....	....	....	214	612	983	...	..	44.0	..	..
Los Angeles	1504	326	266	239	159	90	....	....	....	....	....	123	301	230	30	58.5	88	70
Milwaukee	7245	1383	1201	1023	648	350	39	....	....	84	450	846	1221	284	—10	39.5	93	74
Minneapolis	7850	1609	1400	1094	570	236	....	....	....	93	481	963	1404	275	—20	36.4	93	72
New York	5347	1060	960	837	486	155	....	....	....	....	276	618	955	246	5	43.6	95	75
Oklahoma City	3613	865	742	465	162	....	....	....	....	....	105	459	815	210	—5	47.8	96	76
Omaha	6131	1355	1126	868	414	84	....	....	....	....	329	780	1175	244	—10	39.9	..	..
Philadelphia	4855	1001	893	756	402	68	....	....	....	....	242	588	905	238	5	44.6	95	78
Pittsburgh	5235	1054	944	787	423	78	....	....	....	....	313	669	967	245	—5	43.6	91	73
Portland (Ore.)	4469	806	644	558	402	245	90	....	....	105	332	558	729	304	—15	50.3	83	65
Salt Lake City	5555	1110	885	722	453	236	....	....	....	18	388	723	1020	267	—5	44.2	95	67
San Francisco	3264	465	356	353	294	264	195	202	186	114	146	261	428	365	35	56.0	85	68
Seattle	4966	775	652	623	465	319	168	40	43	192	403	570	716	365	10	51.4	83	61
St. Louis	4585	1060	854	657	276	....	....	....	....	....	205	597	963	221	—5	44.3	..	..
Syracuse	6893	1277	1212	1004	630	267	12	....	....	96	425	798	1172	273	—15	39.8	..	..
Washington, D. C.	4626	970	848	694	348	25	....	....	....	....	251	594	896	236	0	45.4	..	..
Wichita	4673	1094	896	648	252	....	....	....	....	....	192	636	955	226	—5	44.3	..	..

Heating data obtained from Degree Day Handbook published by The Industrial Press.
Cooling data obtained from A. S. H. & V. E. Guide.

CONVERSION TABLES

EQUIVALENTS OF POUNDS PER SQUARE INCH IN FEET OF WATER COLUMN, AND INCHES OF MERCURY COLUMN

Pounds Per Sq. Inch	Feet of Water	Inches of Mercury	Pounds per Sq. Inch	Feet of Water	Inches of Mercury
1	2.31	2.04	20	46.19	40.72
2	4.62	4.07	25	57.73	50.90
3	6.93	6.11	30	69.27	61.08
4	9.24	8.14	35	80.83	71.26
5	11.55	10.18	40	92.38	81.44
10	23.09	20.36	45	103.92	91.62
15	34.64	30.54	50	115.45	101.80

EQUIVALENTS OF OUNCES PER SQUARE INCH IN INCHES OF WATER COLUMN, AND INCHES OF MERCURY COLUMN

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
1	1.73	.13	9	15.59	1.15
2	3.46	.26	10	17.32	1.28
3	5.20	.38	11	19.05	1.4
4	6.93	.51	12	20.78	1.53
5	8.66	.64	13	22.52	1.66
6	10.39	.77	14	24.25	1.79
7	12.12	.89	15	25.98	1.91
8	13.85	1.02	16	27.72	2.04

GENERAL ENGINEERING DATA

CONVERSION TABLES

CONVERSION EQUATIONS

Fahrenheit degrees = 9/5 centigrade degrees +32.

Centigrade degrees = 5/9 (Fahrenheit degrees − 32).

Absolute temperature, expressed in Fahrenheit degrees = Fahrenheit degrees + 459.6. In heating and ventilating work, 460 is usually used.

Absolute temperature, expressed in centigrade degrees = centigrade degrees + 273.1.

CONVERSION TABLE FOR CENTIGRADE TO FAHRENHEIT

For Temperatures Below 0° C.

Temp. ° C.	0	1	2	3	4	5	6	7	8	9
0	+32.0	30.2	28.4	26.6	24.8	23.0	21.2	19.4	17.6	15.8
−10	+14.0	12.2	10.4	8.6	6.8	5.0	3.2	+1.4	−0.4	−2.2
−20	−4.0	5.8	7.6	9.4	11.2	13.0	14.8	16.6	18.4	20.2
−30	−22.0	23.8	25.6	27.4	29.2	31.0	32.8	34.6	36.4	38.2
−40	−40.0	41.8	43.6	45.4	47.2	49.0	50.8	52.6	54.4	56.2
−50	−58.0	59.8	61.6	63.4	65.2	67.0	68.8	70.6	72.4	74.2
−60	−76.0	77.8	79.6	81.4	83.2	85.0	86.8	88.6	90.4	92.2
−70	−94.0	95.8	97.6	99.4	101.2	103.0	104.8	106.6	108.4	110.2
−80	−112.0	113.8	115.6	117.4	119.2	121.0	122.8	124.6	126.4	128.2
−90	−130.0	131.8	133.6	135.4	137.2	139.0	140.8	142.6	144.4	146.2
−100	−148.0	149.8	151.6	153.4	155.2	157.0	158.8	160.6	162.4	164.2

For Temperatures Above 0° C.

Temp. ° C.	0	1	2	3	4	5	6	7	8	9
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2
100	212.0	213.8	215.6	217.4	219.2	221.0	222.8	224.6	226.4	228.2

CONVERSION TABLE FOR FAHRENHEIT TO CENTIGRADE

For Temperatures Below 0° F.

Temp. ° F.	0	1	2		4	5	6	7	8	9
0	−17.78	18.33	18.89	19.44	20.00	20.56	21.11	21.67	22.22	22.78
−10	−23.33	23.89	24.44	25.00	25.56	26.11	26.67	27.22	27.78	28.33
−20	−28.89	29.44	30.00	30.56	31.11	31.67	32.22	32.78	33.33	33.89
−30	−34.44	35.00	35.56	36.11	36.67	37.22	37.78	38.33	38.89	39.44
−40	−40.00	40.56	41.11	41.67	42.22	42.78	43.33	43.89	44.44	45.00
−50	−45.56	46.11	46.67	47.22	47.78	48.33	48.89	49.44	50.00	50.56

For Temperatures Above 0° F.

Temp. ° F.	0	1	2	3	4	5	6	7	8	9
0	−17.78	17.22	16.67	16.11	15.56	15.00	14.44	13.89	13.33	12.78
+10	−12.22	11.67	11.11	10.56	10.00	9.44	8.89	8.33	7.78	7.22
20	−6.67	6.11	5.56	5.00	4.44	3.89	3.33	2.78	2.22	1.67
30	−1.11	−0.56	0.00	+0.56	+1.11	+1.67	+2.22	+2.78	+3.33	+3.89
40	+4.44	5.00	5.56	6.11	6.67	7.22	7.78	8.33	8.89	9.44
50	10.00	10.56	11.11	11.67	12.22	12.78	13.33	13.89	14.44	15.00
60	15.56	16.11	16.67	17.22	17.78	18.33	18.89	19.44	20.00	20.56
70	21.11	21.67	22.22	22.78	23.33	23.89	24.44	25.00	25.56	26.11
80	26.67	27.22	27.78	28.33	28.89	29.44	30.00	30.56	31.11	31.67
90	32.22	32.78	33.33	33.89	34.44	35.00	35.56	36.11	36.67	37.22
100	37.78	38.33	38.89	39.44	40.00	40.56	41.11	41.67	42.22	42.78
110	43.33	43.89	44.44	45.00	45.56	46.11	46.67	47.22	47.78	48.33
120	48.89	49.44	50.00	50.56	51.11	51.67	52.22	52.78	53.33	53.89
130	54.44	55.00	55.56	56.11	56.67	57.22	57.78	58.33	58.89	59.44
140	60.00	60.56	61.11	61.67	62.22	62.78	63.33	63.89	64.44	65.00
150	65.56	66.11	66.67	67.22	67.78	68.33	68.89	69.44	70.00	70.56
160	71.11	71.67	72.22	72.78	73.33	73.89	74.44	75.00	75.56	76.11
170	76.67	77.22	77.78	78.33	78.89	79.44	80.00	80.56	81.11	81.67
180	82.22	82.78	83.33	83.89	84.44	85.00	85.56	86.11	86.67	87.22
190	87.78	88.33	88.89	89.44	90.00	90.56	91.11	91.67	92.22	92.78
200	93.33	93.89	94.44	95.00	95.56	96.11	96.67	97.22	97.78	98.33

POWER, WORK, ETC.

1 ton refrigeration	=	199.038 Btu per minute
Latent heat of ice	=	143.33 Btu per pound
1 Btu	=	776 ft.-lb. 0.293 watt-hours 252.02 mean calories
1 watt hour	=	2,655.2 ft.-lb. 3.415 Btu. 3600 joules 860.648 mean calories
1 mean calorie	=	0.003968 Btu. 3.085 ft.-lb. 0.0011619 watt-hours
1 kilowatt (1000 watts)	=	1.3405 horsepower 56.92 Btu. per minute 44,252.7 ft.-lb. per minute
1 horsepower	=	0.746 kilowatt 42.44 Btu. per minute 33,000 ft.-lb. per minute 550 ft.-lb. per second
1 boiler horsepower	=	33,523.7 Btu. per hour

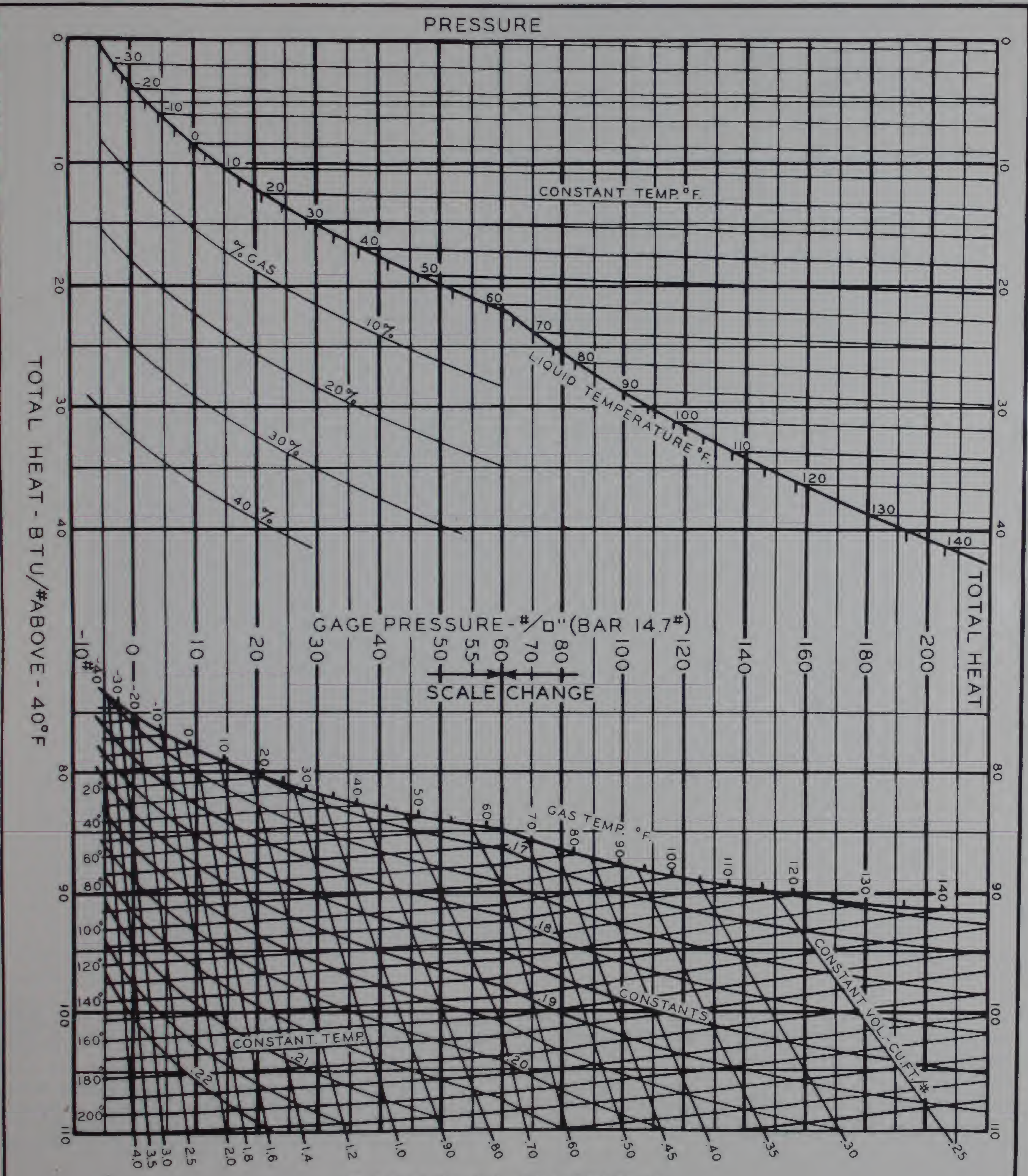
WEIGHT AND VOLUME

1 gal. (U.S.)	=	231. cu. in. 0.13368 cu. ft.
1 British or Imperial gallon	=	277.274 cu. in.
1 cu. ft.	=	7.4805 gal. 1728 cu. in.
1 cu. ft. water at 60° F.	=	62.37 lb.
1 cu. ft. water at 212 °F.	=	59.76 lb.
1 gal. water at 60° F.	=	8.34 lb.
1 gal. water at 212° F	=	7.99 lb.
1 lb. (avdp.)	=	16 oz. 7000 grains
1 bushel	=	1.244 cu. ft.
1 short ton	=	2000 lb.
1 long ton	=	2240 lb.

PRESSURE

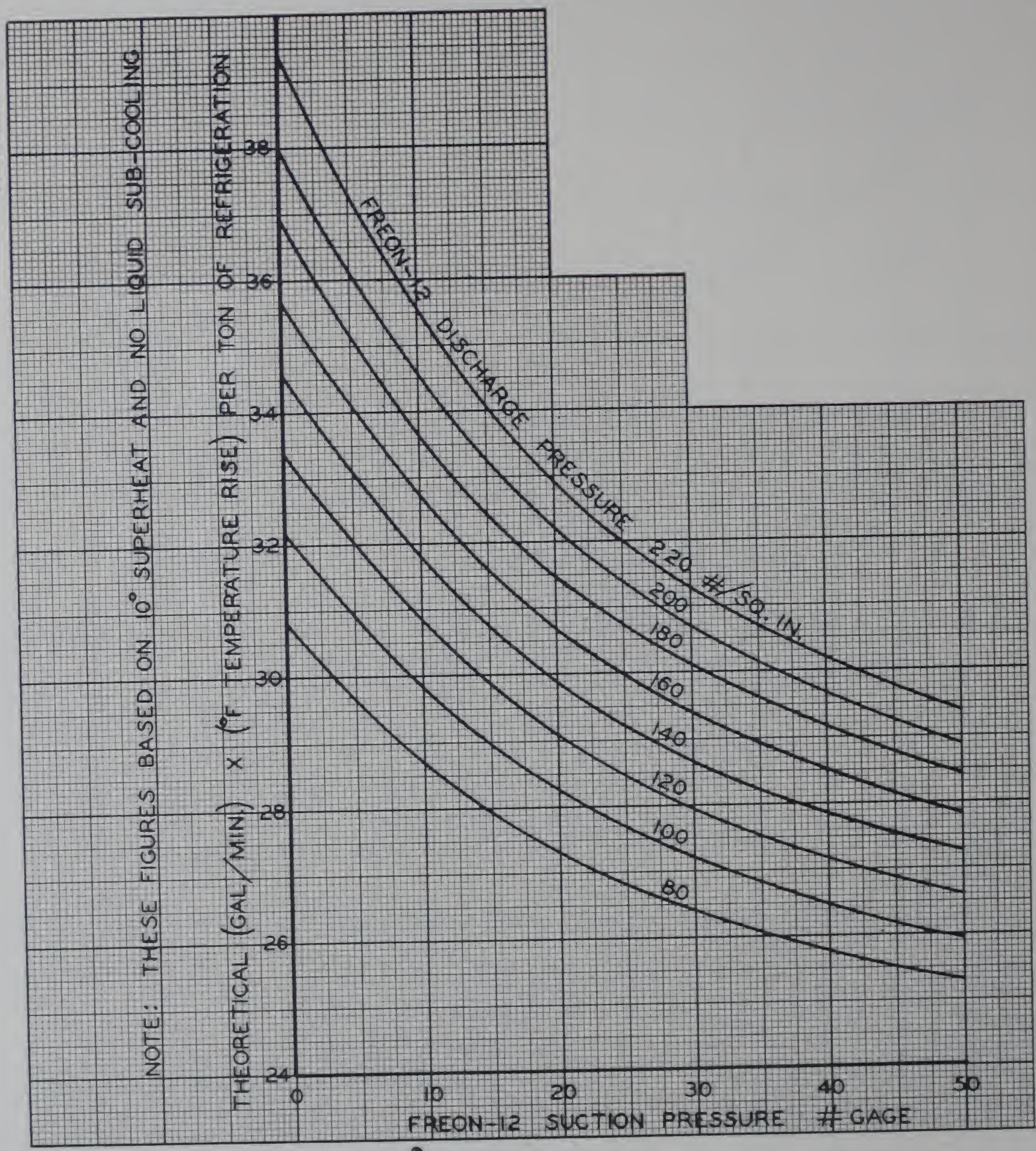
1 lb. per square inch	=	144 lb. per square foot 2.0416 in. mercury at 64° F. 2.309 ft. water at 62° F. 27.71 in. water at 62° F.
1 oz. per square inch	=	0.1276 in. mercury at 62° F. 1.732 in. water at 62° F.
1 atmosphere	=	14.7 lb. per square inch 2116.3 lb. per square foot 33.974 ft. water at 62° F. 30 in. mercury at 62° F. 29.921 in. mercury at 32° F.
1 in. water at 62° F	=	0.03609 lb. per square inch 0.5774 oz. per square inch 5.196 lb. per square foot
1 ft. water at 62° F	=	0.433 lb. per square inch 62.355 lb. per square foot
1 in. mercury at 62° F.	=	0.491 lb. per square inch 7.86 oz. per square inch 1.131 ft. water at 62° F. 13.57 in. water at 62° F.

GENERAL ENGINEERING DATA



PROPERTIES OF FREON-12

GENERAL ENGINEERING DATA



This chart is useful in determining cooling water requirements or the capacity of a condenser water control valve for Freon-12 systems. It may also be used to determine the amount of cooling that is being produced by an existing system.

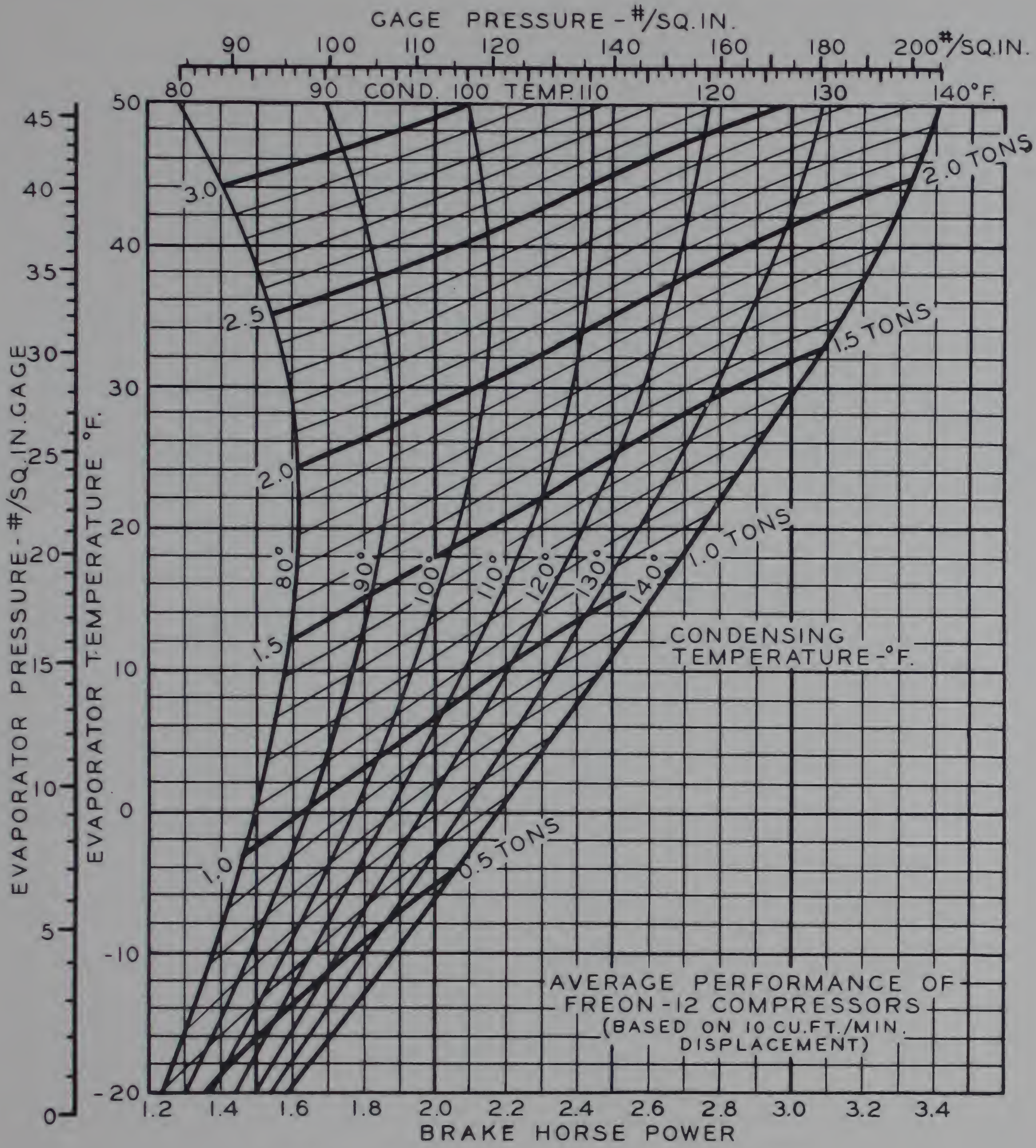
Example No. 1—What will be the cooling water requirements of a 100 ton Air Conditioning System, which operates at 40# suction pressure and 140# discharge pressure if a 10° rise is allowable in the cooling water?

Reference to this chart shows that 27.8 gallon degrees per minute per ton will be required; total gallon degrees equals $27.8 \times 100 = 2{,}780$. Cooling water requirements will then be $\frac{2{,}780}{10} = 278$ gallons per minute. The control valve should be sized accordingly.

Example No. 2—A Freon-12 Air Conditioning System uses 3200 gallons per minute, which shows a temperature rise of 12°, the suction pressure is 35# and the discharge pressure 100#. What tonnage is being produced by the system?

Referring to the chart at 35# suction pressure and 100# discharge pressure 26.8 gallon degrees per ton are required. The tonnage of the system will, therefore, be $\frac{3200 \times 12}{26.8} = 1430$.

GENERAL ENGINEERING DATA



Average Performance of Freon-12 Compressors

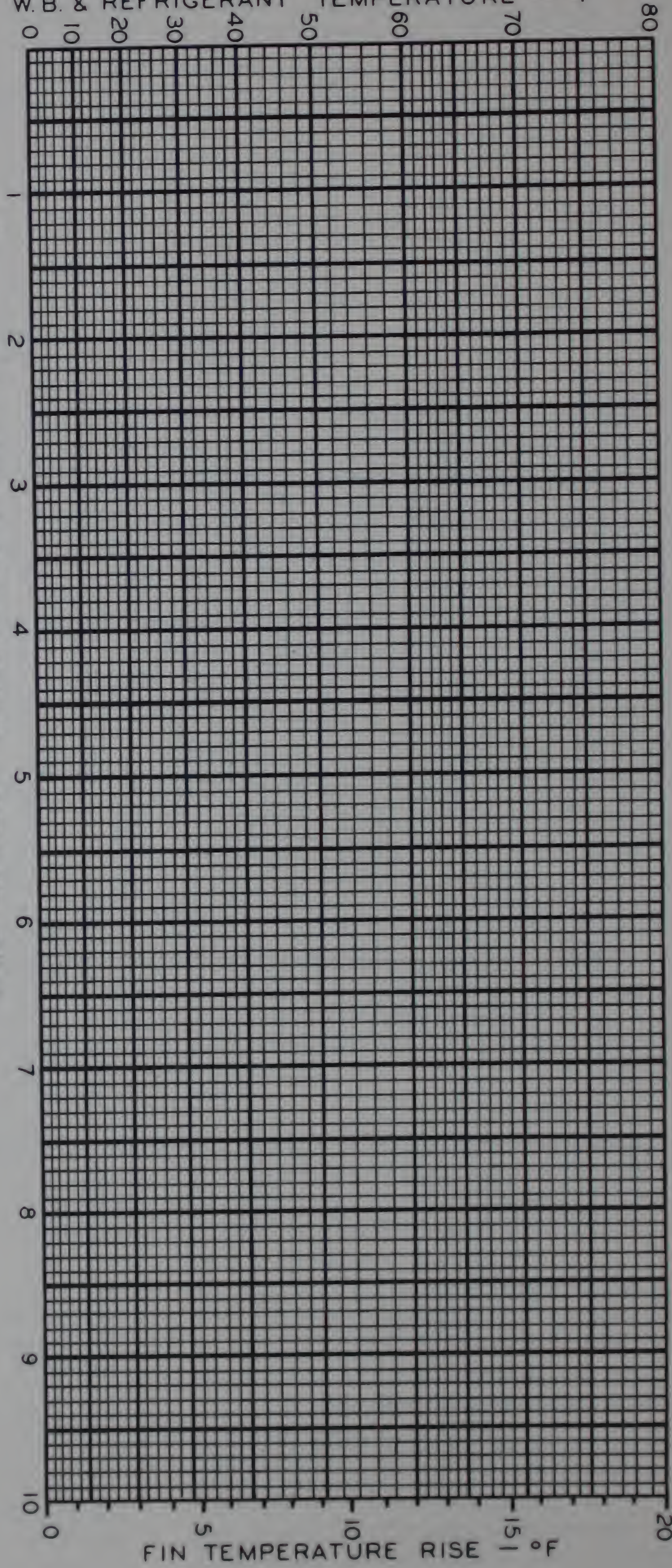
This chart illustrates the average performance characteristics of Freon-12 compressors and is based on a compressor having a piston displacement of 10 cubic feet per minute. Since the capacity of a compressor varies in direct proportion to the piston displacement, this chart may be used for obtaining the capacity and the approximate brake horsepower for other sizes of compressors.

As an example in the use of the chart, assume that the evaporator pressure is 25 lbs. per square inch and the discharge pressure 136 lbs. per square inch on a compressor having 10 cu. ft. per minute displacement. It is desired to find the tonnage of the system and the approximate brake horsepower required. The left-hand scale shows evaporator pressure. From 25 lbs. per square inch on this scale, read to the right to intercept the curved vertical line running down from 136 lbs. per square inch at the top of the chart. This will be found to agree with the 110 degree condensing-temperature line. At the intersection read approximately 1.62 tons refrigeration capacity, on the family of lines mounting upward to the right.

From the same intersection read vertically downward to 2.34 brake horsepower.

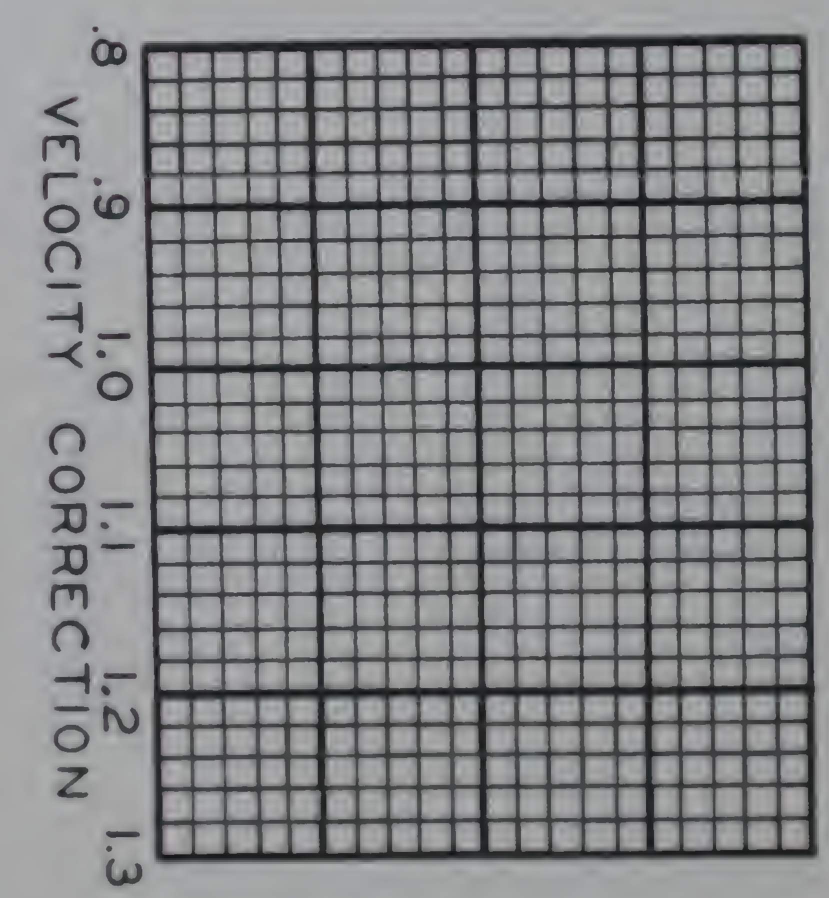
It should be noted that for any given condensing temperature there is some suction pressure at which a definite maximum horsepower is required, and that with a higher or lower suction pressure the horsepower requirements fall off.

GENERAL ENGINEERING DATA

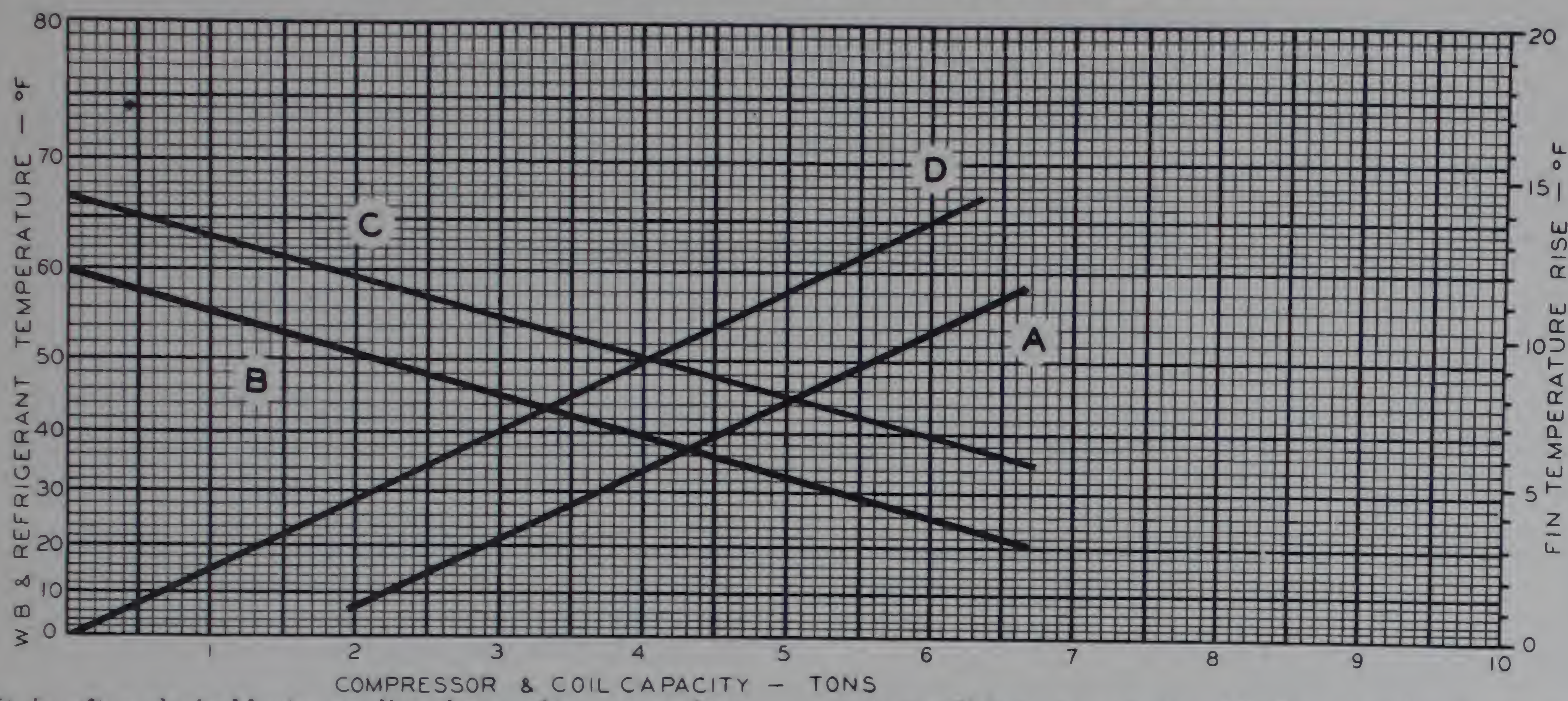


AIR CONDITIONING AND REFRIGERATION

SYSTEM PERFORMANCE CHART



GENERAL ENGINEERING DATA



It is often desirable to predict the performance of an air conditioning system under temperature and relative humidity conditions differing from those under which the system can be tested. It is also, in many cases, desirable to know the effect of changes in the capacity of the evaporators, in the number of evaporators, or in the capacity or number of compressors.

The capacity chart shown above provides a simple method for predicting these results. The scale of this chart is so chosen that when the compressor capacity is plotted against refrigerant temperature, the resulting curve is approximately a straight line. Likewise, when the capacity of an evaporator for a given entering wet bulb temperature is plotted against the refrigerant temperature, the result is also a straight line.

The change in capacity of an evaporator caused by a change in the wet bulb temperature of the entering air may be represented by another straight line parallel to the first and starting at the new wet bulb temperature. The characteristics of the chart permit the prediction of system capacity for a large variety of conditions, and when used with the psychrometric chart, the S/L ratio of the entire system may also be predicted.

As a typical example, refer to the chart above on which curve A shows the capacity of a compressor with a displacement of 20 cubic feet per minute at various refrigerant temperatures and at a constant discharge pressure of 136 lbs. per square inch. It should be noted that this is approximately a straight line and that the capacity varies from 5.56 tons at 50° evaporator temperature to 2 tons at about 7° evaporator temperature.

Curve B represents the capacity of the evaporator used on this system at an entering wet bulb temperature of 60°. The intersection of curves A and B represents the system capacity, that is the capacity of the compressor when used with this particular evaporator and operating under conditions of 60 degrees entering wet bulb temperature. The intersection shows that the resultant system capacity will be 4.3 tons at 37° evaporator temperature.

In practice, curve B would be obtained by plotting the entering wet bulb temperature, thereby establishing a point on the left-hand end of the curve (in this case 60°). The compressor suction pressure is then measured, and the corresponding refrigerant temperature is spotted on the compressor capacity curve A (in this case 37°). A straight line drawn between these two points establishes curve B.

If it is now desired to determine the capacity of the system under design conditions of 67° entering wet bulb temperature, it is only necessary to draw curve C through 67° on the left-hand scale and parallel to curve B. The intersection of curve C with curve A indicates that the system will have a capacity of 5.05 tons and an evaporator temperature of 45° under the new design conditions.

As explained in previous sections of this manual, the S/L ratio may be determined when the difference between the refrigerant temperature and the average fin temperature of the coil is known. By taking readings of the entering wet and dry bulb temperatures and the leaving wet and dry bulb temperatures from the evaporator, and plotting them on the psychrometric chart, the average fin temperature may be found at the intersection with the saturation curve. The intersection of curves A and B on the capacity chart establishes the refrigerant temperature.

It may thus be determined that the difference between the refrigerant temperature and the average fin temperature is 10 degrees. Curve D, which is read on the right-hand scale of the chart, is plotted to show a 10° fin temperature rise at 4.3 tons. By drawing a straight line between the 10° point at 4.3 tons and 0, the approximate fin temperature rise for other conditions may be obtained. Thus at the capacity obtained with a 67° wet bulb temperature, the fin temperature rise will be approximately 11.3 degrees.

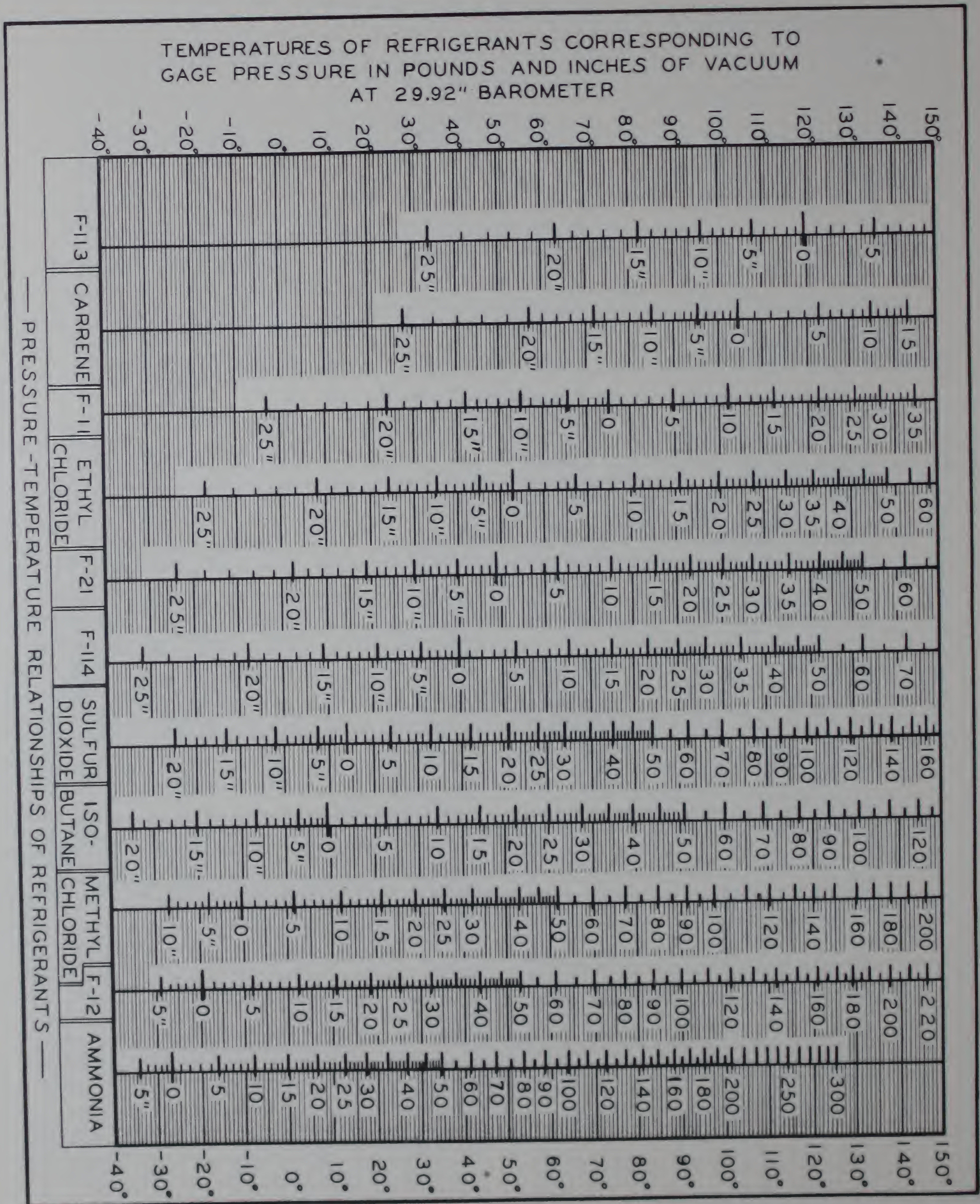
These results, when used with the psychrometric chart, will permit the approximate determination of the S/L ratio of the system.

When the capacity of a compressor is changed or when one or more compressors are used in sequence on a system, the balance pressure for a given coil as the compressor capacity is changed may be obtained by drawing separate curves for the various compressor capacities. Likewise, the effect of changing discharge pressure on the capacity of the system may be determined.

Changes in air velocity over an evaporator in effect change the slope of the curves C and B representing coil capacity. Thus, for a lower air velocity these curves become more steep. When the characteristics of the coil at varying velocities are sufficiently known, the correction curve may be plotted on the chart shown in the lower left-hand corner of Page 173. At velocities less than normal the slope of curves B and C will become steeper because of reduced coil capacity at a given refrigerant temperature. The original curve D for fin temperature rise will still be correct regardless of the air velocity across the coil.

It should be understood that the results which may be obtained from this chart are only approximate but they will usually be found sufficiently accurate for field use. The chart is very useful in plotting the characteristics of an existing air conditioning system so that the effects of changing load conditions may be studied. Knowing these facts, the selection of the most efficient and satisfactory control system becomes a relatively simple problem.

GENERAL ENGINEERING DATA



GENERAL ENGINEERING DATA

ELECTRICAL RATINGS

Voltage

On motor installations it is usually desirable to check the supply voltage at the motor to be sure that it is within 10% above or below the voltage rating of the motor. Since the power output of a motor varies approximately as the square of the voltage it will mean that a 110-volt motor operating on 90 volts will have its power reduced about 33% which in some cases may not enable the motor to start or to reach its rated speed.

Types of Motors

1. Repulsion-induction motors are commonly used on single-phase applications of ¼ H. P. up to as high as 10 H. P. These motors start as repulsion motors and when the speed comes to a pre-determined value, a short circuit device shorts the commutator segments, making the rotor similar to a squirrel cage rotor and causing the motor to assume induction motor characteristics. The rotors of these motors are wound and resemble D. C. armatures having a commutator on one end.

These motors generally have four leads brought out from the stator so that the primary may be connected for 110 or 220 volts externally. The direction of rotation is changed on most makes by shifting the position of the brushes.

2. Split-phase motors are generally used on applications of 1/6 H. P. and smaller. They have two windings, a starting winding, which is cut out of the circuit by a starting switch when the motor comes up to a predetemined speed, and a main winding.

These are also considered constant speed motors, as they have induction motor characteristics when running. They are not dual-voltage motors as are the repulsion-induction motors and can only be used on the voltage stamped on the name plate. To reverse the direction of rotation it is only necessary to reverse the starting winding leads which causes the motor to start in the opposite direction.

3. Poly-phase motors of the squirrel-cage type are used for all general applications on two and three-phase circuits where variable speed is not required. These motors are exceptionally simple and rugged, having no short-circuiting or starting switches and no wound rotors.

Two-phase motors may be reversed by inter-changing the two leads of one phase.

Three-phase motors are reversed by reversing any two leads.

TABLE NO. 1
Full Load Current for A. C. Motors

H. P.	SINGLE PHASE		THREE PHASE INDUCTION TYPE		
	110 V.	220 V.	110 V.	220 V.	440 V.
⅛	3.34	1.67	—	—	—
¼	4.8	2.4	—	—	—
½	7	3.5	5	2.5	1.3
¾	9.4	4.7	5.4	2.8	1.4
1	11	5.5	6.6	3.3	1.7
1½	15.2	7.6	9.4	4.7	2.4
2	20	10	12	6	3
3	28	14	—	9	4.5
5	46	23	—	15	7.5
7½	68	34	—	22	11
10	86	43	—	27	14
15	—	—	—	38	19
20	—	—	—	52	26
25	—	—	—	64	32
30	—	—	—	77	39
40	—	—	—	101	51
50	—	—	—	125	63

TABLE NO. 2
Conductor Sizes and Overcurrent Protection for Motors

Full Load Current Rating of Motor	Minimum Allowable Size of Copper Wire, Am. gauge or cir. mils.			For Running Protection of Motors		Maximum Allowable Rating of Branch Circuit Fuses		D. C. and Wound Rotor A. C.
				Maximum Rating of N. E. C. Fuses	Max. Setting of time-limit protective device	Single Phase and Squirrel cage and Synchronous (full-voltage, reactor and resistor starting.)	Squirrel-cage and Synchronous (auto-transformer starting.) High-reactance Squirrel-cage	
Amperes Col. 1	Rubber 2	Varnished Cambric 3	Slow Burning 4	Amperes 5	Amperes 6	Amperes 7	Amperes 8	Amperes 9
1	14	14	14	2	1.25	15	15	15
2	14	14	14	3	2.50	15	15	15
3	14	14	14	4	3.75	15	15	15
4	14	14	14	6	5.0	15	15	15
5	14	14	14	8	6.25	15	15	15
6	14	14	14	8	7.50	20	15	15
7	14	14	14	10	8.75	25	20	15
8	14	14	14	10	10.0	25	20	15
9	14	14	14	12	11.25	30	25	15
10	14	14	14	15	12.50	30	25	15
11	14	14	14	15	13.75	35	30	20
12	14	14	14	15	15.00	40	30	20
13	12	14	14	20	16.25	40	35	20
14	12	14	14	20	17.50	45	35	25
15	12	12	14	20	18.75	45	40	25
16	12	12	14	20	20.00	50	40	25
17	10	12	12	25	21.25	60	45	30
18	10	12	12	25	22.50	60	45	30
19	10	12	12	25	23.75	60	50	30
20	10	12	12	25	25.0	60	50	30
22	8	10	10	30	27.50	70	60	35
24	8	10	10	30	30.00	80	60	40
26	8	8	8	35	32.50	80	70	40
28	8	8	8	35	35.00	90	70	45
34	6	6	8	45	42.50	110	70	60
40	6	6	8	50	50.00	125	80	60
68	2	4	4	90	85.00	225	150	110
86	0	2	2	110	107.50	300	175	150

M-H ENGINEERING DATA

GENERAL RULE FOR CONDUIT SIZE FOR ANY NUMBER OF WIRES

The size of the conduit for any number of wires of various sizes may be calculated as follows: Find the total number of circular inches* of area of insulated wire to be put in the conduit and divide by a factor of .4. (This factor applies only to calculations for four or more wires.) The result will be the number of circular inches of inside area required in the conduit. The square root of this figure gives the inside diameter of the required conduit.

Example: Find the size of conduit required for 2 #14 and 6 #18 wires.

Overall diameter of #14 wire = .20″
Overall diameter of #18 wire = .14″
2(.20 × .20) = .08 circular inches for 2 #14's
6(.14 × .14) = .1176 circular inches for 6 #18's

Total = .1976 circular inches

$$\frac{.1976}{.4} = .494 \text{ circulator inches of inside area of conduit.}$$

$$\sqrt{.494} = .703'' \text{ inside diameter}$$

Therefore use ¾″ conduit.

*The area in circular inches of any circle is equal to the square of its diameter in inches.

TABLE NO. 3

NUMBER OF WIRES OF ONE SIZE IN A CONDUIT

Conduit Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
Internal Diameter	0.62	0.82	1.049	1.38	1.61	2.06	2.46	3.06
#18 Single Braid [illegible]″	8	13	22	39	52	86	122	190
3-Wire Stat Cable	5	8	11	20	27	44	62	96
#16 Single Braid [illegible]″	6	11	18	31	42	69	99	153
#14	4	7	11	19	26	42	60	94
#12	3	5	8	17	23	38	54	84
#10	1	4	6	14	19	32	45	70
#8	1	3	5	10	14	23	33	51
#6	1	1	2	4	6	10	—	—
#5	0	1	1	4	5	9	—	—
#4	0	1	1	3	4	8	—	—
#3	0	1	1	3	4	7	—	—
#2	0	1	1	2	4	6	—	—
#1	0	1	1	1	3	5	—	—
#0	0	0	1	1	2	4	—	—

TABLE NO. 4

2—#16's and Any Number of #18 Wires								
Conduit Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
Number of #18	5	11	19	36	52	83	120	187
2—#14's and Any Number of #18 Wires								
Conduit Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
Number of #18	3	9	18	34	50	82	118	186
2—#12's and Any Number of #18 Wires								
Conduit Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
Number of #18	3	9	17	34	50	81	118	185

TABLE NO. 5

PHYSICAL CONSTANTS FOR WIRE
600-VOLT RUBBER-INSULATED COPPER WIRE
Single Braid, N.E.C. Standard: Conductivity of Copper, 98%.

Size A.W.G.	Cross Section of Copper Circular Mils	Over-all Diameter Inches (Stranded)	Ohms per 1000 Feet at 77° F. (Stranded)	Pounds per 1000 Feet of Insulated Wire (Stranded)
00	133,000	0.66	0.02827	535
0	106,000	0.61	0.104	438
1	83,700	0.57	0.133	350
		Solid	Solid	Solid
1	83,700	0.53	0.126	340
2	66,400	0.47	0.159	268
3	52,600	0.44	0 201	221
4	41,700	0.41	0.253	184
5	33,100	0 39	0.320	153
6	26,300	0.37	0.403	129
8	16,500	0 27	0.641	76
10	10,400	0.23	1.02	54
12	6,530	0 21	1.62	40
14	4,110	0.20	2.58	30
16	2,580	0 16	4.10	20
18	1,620	0 14	6.51	13

TABLE NO. 6

MAXIMUM CURRENT CAPACITY OF WIRES
MAXIMUM ALLOWABLE AMPERES

Size of Wire A.W.G.	Rubber Insulation	Varnished Cambric Insulation	Other Insulations
18	3	—	5
16	6	—	10
14	15	18	20
12	20	25	25
10	25	30	30
8	35	40	50
6	50	60	70
5	55	65	80
4	70	85	90
3	80	95	100
2	90	110	125
1	100	120	150
0	125	150	200

M-H ENGINEERING DATA

CONDENSATION IN COMPRESSED AIR PIPING

Chart is used to determine the maximum water vapor content of compressed air at various temperatures and pressures.

Assume air at 80° F. and 80% relative humidity is taken into an air compressor, compressed to 30 lbs. per sq. inch, and delivered to a tank that is maintained at 90° F. Referring to a psychometric chart, it is found that air at 80° F. and 80% relative humidity contains 123 grains of water vapor per pound of dry air. Referring to the chart it is found that air at 90° F. (tank temperature) and at 30 lbs. pressure is saturated with 68 grains per pound of dry air. Therefore during compression the air will give up 55 grains of water vapor, per pound of dry air, which will collect in the bottom of the tank.

If this air is reduced to 15 pounds pressure and delivered from the tank to a pneumatic control system air main, the moisture content will remain at 68 grains per pound of dry air. Referring to the chart, it is found that air at 15 pounds pressure and with 68 grains of moisture is saturated at a temperature of 78° F. Since 78° F. is the saturation or dew point temperature of the air in the main, moisture will condense in the main if the temperature of the main drops below 78° F. This clearly indicates the necessity for a moisture condenser on summer cooling pneumatic control installations.

The advisability of using a compressor operating at high pressures instead of a moisture condenser to remove moisture from the air is often questioned. The usual specifications for a high pressure air supply state that the compressor shall operate to maintain an average tank pressure of 70 pounds per square inch. During the summer, air in such a storage tank will probably reach a temperature of 100° F. or higher due to ambient temperatures of the tank and the heat of compression. Referring to the chart, it is found that air at 100° F. and at 70 pounds pressure is saturated with 49 grains of water vapor per pound of dry air. During compression all moisture above that amount will condense and accumulate in the bottom of the storage tank. When this air is reduced to 15 pounds pressure, it is found from the chart that its dew point temperature is 68° F. Due to the fact that on summer cooling control installations some portion of the air piping, particularly around the conditioner, may be subjected to temperatures below 68° F., it is obvious that a system of this kind is not satisfactory.

It would appear that if the air in the storage tank could be maintained at a pressure sufficiently high and at a temperature sufficiently low the problem would be solved. This is true but from a practical standpoint, does not often work out. As the tank pressure is increased, air temperature is increased due to the heat of compression and power requirements increase due to the higher compression ratio. This requires a much larger compressor motor for a given air output which increases compressor costs. Actually, it is cheaper to provide a suitable moisture condenser than to supply a compressor for high pressures on a given installation.

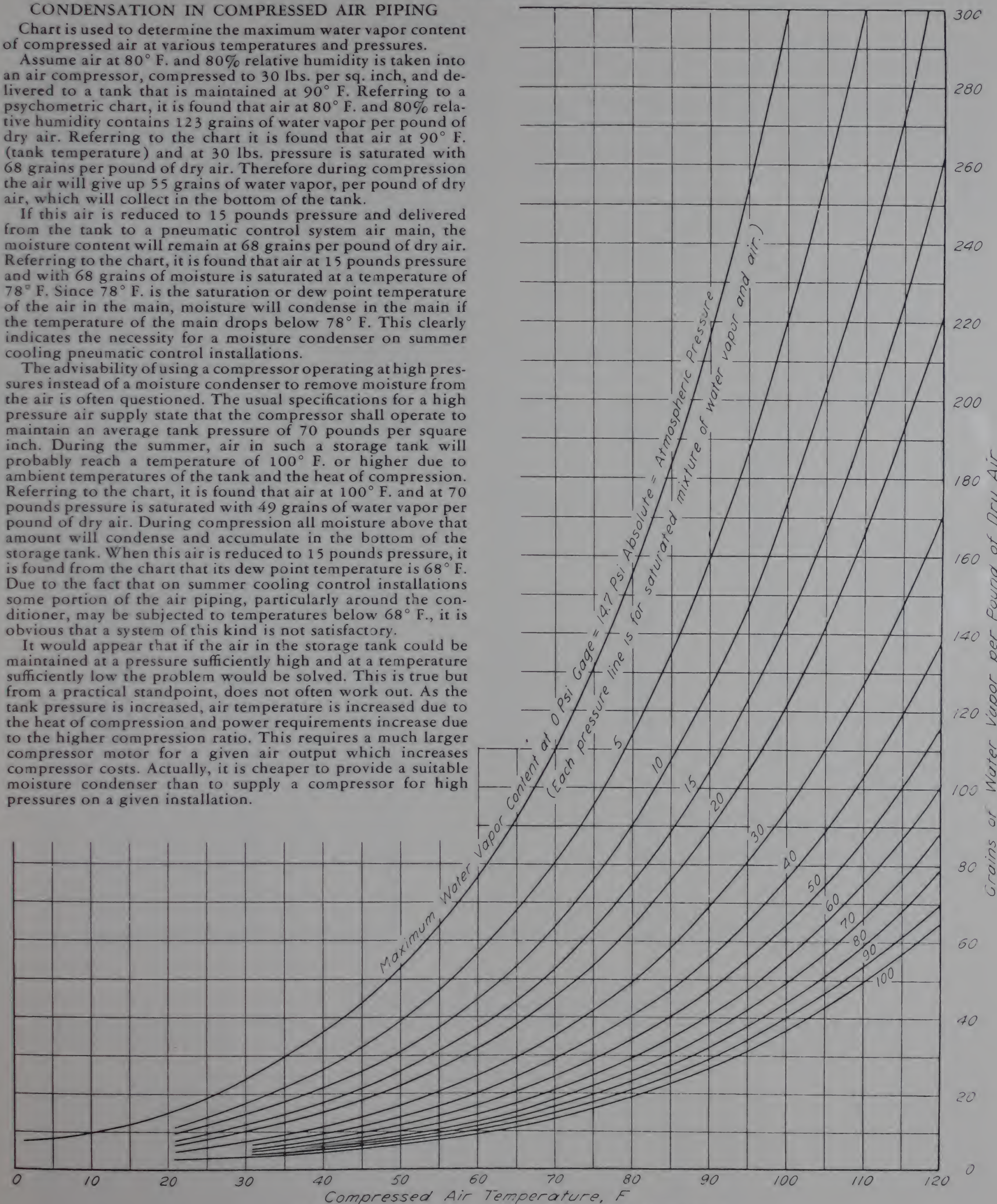


Chart Reprinted with the permission of G. M. Brown

M-H ENGINEERING DATA

VALVE SELECTION

The kind of fluid passed through the valve often dictates the kind of metal the valve is to be made of, as some fluids have a very corrosive action on certain kinds of metal.

The pressure and temperature of the fluid is also important especially when it is desired to use double seated valves, as these valves are ground in at the factory to close tightly under certain conditions of service. In other words, if the valve is ground in for hot service it cannot close tightly when used on cold service. The opposite is also equally true. Composition discs for single seated valves are furnished for service within specified pressure and temperature ranges.

Stainless steel trim with semi-steel body should be specified for high pressure steam service.

The capacity of a steam valve for use on fan heating coils may be determined from the following formula:

$$Q = \frac{(CFM) \times 1.0 \times (T_b - T_m)}{1000}$$

Where: Q = lbs. of steam per hour.
T_b = Maximum discharge air temperature desired.
T_m = Th m.nimum temperature of mixed ourdoor and return air delivered to the coil.

When sizing valves for steam coil service the drop through the valve is assumed to be about 40% or 50% of the inlet pressure. For 5-lb. gauge a 2-lb. pressure drop and for a 2-lb. gauge a 1-lb. pressure drop may be assumed in normal cases. If the valves are close to the source of supply, higher pressure drops may be expected. Allowance for special conditions should always be made in assuming pressure drops.

It is very important that Modulating Valves should not be over-sized since the modulating range of the valve will be decreased. In other words, if the maximum flow requirements are satisfied when the valve is only partially opened, it is evident that additional movement of the modulating motor towards the open position will have no effect upon the control medium. Since the number of effective motor positions are reduced it follows that good modulation cannot be attained. Wire drawing is also more pronounced in over-sized valves because the valve is usually operating near the closed position.

Two-position or "on-and-off" valves are usually sized with reference to the size of pipe they are to be installed in. If, however, the pipes are greatly over-sized, there is no need to purchase an oversized valve which is more expensive than a smaller accurately sized valve. Reducers may be installed in conjunction with the correct valve size if economies can be effected by sizing.

The chart on page 18 provides a convenient means for determining the proper size electric or pneumatic valve to use on the heating coil of a fan system.

PROPERTIES OF SATURATED STEAM

Vacuum Inches of Mercury	Absolute Pressure lbs. per Sq. Inch	Boiling Point or Steam Temp.	Volume of 1 lb. of Steam cubic ft.	Heat of the Liquid Btu.	Latent Heat of Evap. Btu.	Total Heat of Steam Btu.
29	.452	76.62	706.	44.66	1048.6	1093.2
28	.944	99.93	351.5	67.90	1035.6	1103.6
27	1.435	114.22	236.8	82.15	1027.7	1109.8
26	1.926	124.77	179.5	92.67	1021.7	1114.4
25	2.417	133.22	145.0	101.10	1017.0	1118.1
24	2.908	140.31	121.9	108.18	1012.9	1121.1
23	3.399	146.45	105.4	114.31	1009.4	1123.8
22	3.890	151.87	92.9	119.73	1006.3	1126.0
21	4.382	156.75	83.1	124.61	1003.5	1128.1
20	4.873	161.19	75.2	129.05	1001.0	1130.0
19	5.364	165.24	68.7	133.10	998.6	1131.7
18	5.855	169.00	63.3	136.86	996.4	1133.3
17	6.346	172.51	58.7	140.38	994.3	1134.7
16	6.837	175.80	54.7	143.67	992.4	1136.1
15	7.329	178.91	51.3	146.79	990.6	1137.4
14	7.82	181.82	48.30	149.71	988.8	1138.5
13	8.31	184.61	45.61	152.50	987.1	1139.6
12	8.80	187.21	43.27	155.11	985.6	1140.7
11	9.29	189.75	41.12	157.66	984.0	1141.7
10	9.78	192.19	39.16	160.10	982.6	1142.7
9	10.28	194.50	37.41	162.42	981.2	1143.6
8	10.77	196.73	35.81	164.65	979.9	1144.5
7	11.26	198.87	34.35	166.81	978.5	1145.3
6	11.75	200.96	32.99	168.90	977.2	1146.2
5	12.24	202.92	31.77	170.87	976.0	1146.9
4	12.73	204.85	30.62	172.81	974.8	1147.6
3	13.22	206.70	29.56	174.67	973.7	1148.4
2	13.71	208.50	28.58	176.48	972.5	1149.1
1	14.20	210.25	27.67	178.24	971.4	1149.7
Pounds Gauge						
0	14.70	212.0	26.79	180.00	970.4	1150.4
1	15.70	215.3	25.20	183.3	968.2	1151.6
2	16.70	218.5	23.78	186.6	966.2	1152.8
4	18.70	224.4	21.40	192.5	962.4	1154.9
6	20.70	229.8	19.45	198.0	958.8	1156.8
8	22.70	234.8	17.85	203.0	955.5	1158.6
10	24.70	239.4	16.49	207.7	952.5	1160.2
15	29.70	249.8	13.87	218.2	945.5	1163.7
25	39.70	266.8	10.57	235.6	933.6	1169.2
50	64.70	297.7	6.68	267.2	911.2	1178.4
75	89.70	320.1	4.91	290.3	894.2	1184.4
100	114.70	337.9	3.891	308.8	880.0	1188.8
125	139.70	352.9	3.225	324.4	867.8	1192.2

Three-Way Valves with M-H-R Valve Bodies
WATER Capacities in Gals. Per Min.

M.H.R. Valve Body—Metaphram Three-Way Valve V581A and V581B (Available thru 2") Assembly Nos. K910A, K0903B, V055A, V055B, V055C

PRESSURE DROP ACROSS VALVE—LBS.

Valve Size	1	2	5	10	15	20	25	30	35	40	50	60	70
½"	3.6	5.1	8.0	11.2	13.5	15.5	17.3	19.1	20.6	21.8	24	27	29
¾"	6.4	8.8	14.0	19.8	24.0	27.0	30	33	36	38	42	47	50
1"	11.9	16.6	26.0	37.0	44.5	51	56	63	67	71	79	88	94
1¼"	23	32	50	72	86	99	110	122	130	139	153	171	184
1½"	34	48	75	107	129	145	164	180	192	206	228	253	270
2"	63	89	140	198	238	270	300	335	360	380	425	470	505
2½"	77	110	174	235	290	328	368	415	445	465	500	560	600
3"	97	132	205	293	350	400	450	490	510	545	620	680	725
4"	66	235	375	520	625	730	790	875	940	1000	1090	1200	1310
5"	244	340	535	730	900	1030	1160	1260	1340	1430	1580	1720	1870
6"	350	490	750	1180	1290	1500	1670	1820	1940	2020	2260	2480	2700

M-H ENGINEERING DATA

VALVE CAPACITIES—WATER

TABLE NO. 1

M-H-R Single Seated—Throttling Guide
WATER Capacities in Gals. Per Min.

MHR Valve Body V575A and V575B — **Assembly Nos. K200, K900, V053, K0900**

Valve Size	DIFFERENTIAL PRESSURE 1	2	5	10	15	20	25	30	35	40	50	60	70
¼	1.1	1.8	2.2	3.1	3.8	4.4	4.8	5.3	5.7	6.1	6.8	7.5	8.0
⅜	1.8	2.5	3.9	5.5	6.5	7.5	8.4	9.3	10.0	11.0	12.0	13.0	14.0
½	3.0	4.2	6.6	9.3	11.2	12.8	14.3	15.8	17.0	18.0	20.0	22.2	23.8
¾	5.7	7.9	12.5	17.7	21.3	24.3	27.2	30.0	32.0	34.0	37.8	42.0	45.0
1	8.7	12.1	19.0	27.0	32.5	37.0	41.3	45.8	48.7	52.0	57.8	64.0	69.0
1¼	15.8	21.7	34.7	49.3	59.3	67.8	75.7	83.7	89.0	95.0	105	117	126
1½	20.2	28.3	44.2	62.7	75.7	86.3	96.3	106	113	121	134	149	160
2	29.2	40.8	64.2	91.0	109	124	139	154	164	175	195	216	232
2½	39.2	54.2	86.3	122	147	167	187	207	220	235	261	290	312
3	48.3	66.7	106	150	181	207	231	255	271	290	323	358	380

50% capacity guides are available in ¼", ⅜" and ½" sizes only.

TABLE NO. 2

Double Seated Bevel Seated Valves
WATER Capacities in Gals. Per Min.

MHR Valve Body No. V537F — **Assembly No. K201A** — **(Fisher No. 5120)**

Valve Size	DIFFERENTIAL PRESSURE 1	2	5	10	15	20	25	30	35	40	50	60	70
½"	4.	5.5	8.7	12.	14.9	17.	18.9	20.7	22.3	23.7	26.6	29.	31.4
¾"	7.	9.6	15.3	21.	25.9	29.4	32.9	36.5	38.9	42.	46.9	51.	54.8
1"	13.2	18.3	28.1	39.9	48.7	55.7	61.3	68.2	73.5	78.4	87.6	95.5	104.
1¼"	17.4	24.5	37.5	53.3	64.2	74.6	82.8	90.7	96.7	104.	116.	127.	138.
1½"	29.2	38.	59.9	86.9	104.	120.	132.	145.	157.	166.	186.	200.	216.

TABLE NO. 3

Double Seated Characterized V-Ported Valves
WATER Capacities in Gals. Per Min.

MHR Valve Body V537B — **Assembly Nos. K201B and K901B** — **(Fisher No. 5007)**

Valve Size	DIFFERENTIAL PRESSURE 1	2	5	10	15	20	25	30	35	40	50	60	70	80	90	100	125	150
½	6.3	8.8	13.8	20	23.3	26.7	30	33.3	36.3	39.6	43.3	46.7	50	53.3	57.5	60.8	66.7	75
¾	8.3	11.7	20.0	26.3	31.7	36.7	41.3	45.	48.3	51.7	58.3	63.3	66.7	73.3	76.7	80	91.7	100
1	16.7	24.2	36.7	51.7	63.3	73.3	82.7	90.	96.7	104.2	116.7	125	137.5	145.8	158.3	166.7	183.3	200
1¼	22.9	31.7	50.0	71.7	87.5	100	110.	121.7	133.3	141.7	150.	175	183.3	200.	212.5	218.3	241.7	266.7
1½	32.5	45.8	73.3	100.0	120.8	140.	154.2	175.	183.3	200.	216.7	241.7	262.5	275.	291.7	316.7	350.	383.3
2	53.3	75.0	116.7	166.7	200.0	229.2	250.	279.2	300.	320.	366.7	400	430	466.7	483.3	512.5	566.7	633.3
2½	66.7	91.7	145.8	201.7	246.7	283.3	316.7	350.	375.	400.	450.	491.7	533.3	566.7	600.	633.3	708.3	766.7
3	115.	160.	250.	350.	425.	487.	523.	600.	641.	683.	766.	833.	900.	950.	1016.	1067.	1200.	1300.
3½	133.	186.	287.	408.	491.	568.	625.	700.	750.	800.	883.	950.	1033.	1116.	1167.	1250.	1383.	1500.
4	148.	205.	325.	448.	550.	625.	700.	766.	816.	883.	983.	1067.	1140.	1233.	1300.	1383.	1630.	1650.
5	288.	405.	625.	883.	1066.	1233.	1366.	1500.	1614.	1750.	1883.	2083.	2233.	2383.	2533.	2683.	2966.	3250.
6	333.	466.	733.	1033.	1350.	1433.	1600.	1733.	1867.	2000.	2233.	2416.	2616.	2800.	2966.	3116.	3466.	3800.

TABLE NO. 4

WATER Capacities in Gals. Per Min.

MHR Valve Body V578A — **Assembly Nos. K0901, V054**

Valve Size	DIFFERENTIAL PRESSURE 1	2	5	10	15	20	25	30	35	40	50	60	70
½"	4.7	6.7	10.6	14.6	18.4	20.8	23.3	25.0	26.7	28.3	31.7	35.0	38.3
¾"	7.7	10.8	17.4	24.0	29.5	34.2	38.8	42.0	44.2	48.0	53.5	58.0	64.5
1"	11.6	16.4	25.2	35.4	43.7	49.1	57.2	61.3	64.0	69.4	77.0	85.0	92.7
1¼"	15.4	21.7	34.3	47.7	58.7	67.3	74.2	80.0	84.0	91.0	101	110	120
1½"	20.3	29.0	44.5	63.2	77.0	87.8	98.6	106	112	121	135	148	162
2"	27.5	39.4	60.5	84.5	101	118	133	146	153	166	184	203	221
2½"	41.7	56.8	86.8	121	150	180	191	209	225	242	267	292	309
3"	51.1	70.8	109	157	190	212	241	263	277	307	336	365	394

M-H ENGINEERING DATA

VALVE CAPACITIES—WATER (Cont.)

Three-Way and Pilot Operated Valves
WATER Capacities in Gals. Per Min.

TABLE NO. 5
MHR Valve Body Nos.:
Pilot Operated, V58A, V58B, V58C
Three-Way, V538B (Available up to 4" inclusive)

Assembly Nos.:
K202A, K202B, K202C
K203A, K903A

	DIFFERENTIAL PRESSURE												
Valve Size	1	2	5	10	15	20	25	30	35	40	50	60	70
½"	2.25	3.2	5.1	7.2	9	10.5	11.6	13	14	15	16.7	18.2	20
¾"	5	7	10.4	16.3	20	23	26.5	28.5	31	33.5	37	42	44
1"	8.8	12.5	20	28	35	40	47	51	55	58	64	73	78
1¼"	14.9	19.1	31	44	55	63	71	79	85	91	100	111	122
1½"	19.5	27.5	44.5	62.5	78	90	100	111	120	130	145	162	173
2"	34.5	50	80	112	140	163	182	200	200	230	250	285	310
2½"	53	74	120	170	210	235	275	300	325	350	385	430	470
3"	78	112	177	250	310	355	410	445	480	520	585	650	700
3½"	107	152	235	340	425	490	550	600	660	700	775	870	950
4"	138	194	310	440	545	635	705	770	840	900	1010	1125	1200
5"	210	300	470	680	840	980	1110	1200	1300	1400	1570	1730	1880
6"	300	420	670	970	1080	1390	1550	1700	1850	1950	2200	2400	2600

TABLE NO. 6
Packless Radiator Type Valves

WATER Capacities in Gals. Per Min.

Assembly Nos. V205 and V605

		DIFFERENTIAL PRESSURE								
Valve Size	Valve Type	1	2	5	10	15	20	25	25	35
¾"	Straight Thru	7.0	9.6	15.0	20.4	25.8	29.3	32.6	35.8	38.3
1"	Straight Thru	11.5	16.1	25.0	35.0	43.3	50.0	......	......	......
1¼"	Straight Thru	14.3	20.0	30.8	43.3	53.3	......	......	......	......
1½"	Straight Thru	22.5	31.0	48.3	68.3	......	......	......	......	......
2"	Straight Thru	38.3	53.3	83.3	118.3	......	......	......	......	......
¾"	Angle	8.6	11.8	19.1	26.6	32.0	38.0	41.6	45.0	49.1
1"	Angle	18.7	26.5	41.6	57.5	70.0	80.0	......	......	......
1¼"	Angle	20.3	28.3	45.0	63.3	76.6	......	......	......	......
1½"	Angle	31.6	44.1	70.0	95.8	......	......	......	......	......
2"	Angle	50.8	71.6	112.5	158.3	......	......	......	......	......

VALVE CAPACITIES—STEAM

MHR Single Seated V-Ported Valves
STEAM Capacities in Lbs. Per Hour (Standard Guide)

TABLE NO. 7
MHR Valve Body V575A and V575B

Assembly Nos. K200B, K900, V053, K0900

Valve Size	INLET GAGE PRESSURE																	
	2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.			
	DIFFERENTIAL PRESSURE																	
	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15
¼"	10	13	11	14	16	20	16	23	26	32	18	28	35	42	22	31	42	50
⅜"	18	24	20	26	32	39	31	44	50	60	33	53	65	77	41	60	78	95
½"	32	42	35	46	55	68	53	77	87	100	60	94	115	135	68	100	135	160
¾"	57	75	62	82	98	121	96	140	158	182	110	170	205	240	120	182	240	280
1"	90	120	98	130	156	193	152	220	250	290	174	265	320	380	190	290	380	440
1¼"	160	210	175	230	275	340	270	390	440	510	310	480	580	680	340	510	680	780
1½"	190	250	205	270	325	400	320	460	520	600	350	550	680	800	400	600	800	950
2"	300	390	330	430	510	630	510	740	840	930	560	880	1080	1260	640	930	1260	1500
2½"	390	510	430	560	670	830	650	950	1080	1240	740	1150	1410	1650	830	1240	1650	1900
3"	520	670	560	740	890	1100	860	1250	1420	1600	970	1520	1860	2180	1100	1600	2180	2500

50% capacity guides are available in ¼", ⅜" and ½" sizes only.

TABLE NO. 8
MHR Valve Body No. V537F

Double Seated Bevel Seated Valves
STEAM Capacities in Lbs. Per Hour

Assembly No. K201A
(Fisher No. 5120)

Valve Size	INLET PRESSURE																		
	2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.				
	DIFFERENTIAL PRESSURE																		
	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15	25
½"	37	49	41	56	64	82	62	91	104	119	68	109	131	156	82	117	153	184	224
¾"	66	89	74	102	118	144	114	162	186	218	124	194	240	283	144	212	279	331	407
1"	122	164	140	185	220	272	212	309	351	408	233	361	451	535	272	401	526	622	761
1¼"	171	223	188	254	296	373	282	411	475	549	318	498	618	720	373	540	705	843	1022
1½"	264	358	301	403	461	575	451	652	752	872	502	783	972	1121	575	859	1119	1316	1620

M-H ENGINEERING DATA

VALVE CAPACITIES—STEAM (Cont.)

TABLE NO. 9 — Double Seated Characterized V-Ported Valves — Assembly Nos. K201B and K901B
MHR Valve Body No. V537B — STEAM Capacities in Lbs. Per Hour — (Fisher No. 5007)

VALVE SIZE	INLET GAGE PRESSURE 2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.				
DIFFERENTIAL PRESSURE	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15	25
½"	65	85	70	95	110	140	105	150	180	200	120	180	230	260	140	200	260	305	360
¾"	95	120	110	140	160	200	160	230	260	300	180	280	340	400	200	300	400	460	550
1"	160	220	180	240	280	350	280	400	450	530	300	480	600	700	350	520	700	810	950
1¼"	260	350	300	380	450	550	450	650	730	850	500	760	950	1100	570	850	1100	1300	1500
1½"	350	460	400	510	600	750	600	850	1000	1120	650	1050	1280	1500	760	1100	1460	1780	2000
2"	600	770	650	860	1000	1280	1000	1400	1610	1900	1100	1770	2200	2500	1300	1900	2500	3000	3500
2½"	750	1000	850	1120	1300	1600	1270	1810	2100	2410	1400	2200	2700	3200	1610	2400	3200	3750	4400
3"	1300	1700	1400	1850	2200	2700	2100	3000	3400	4000	2300	3750	4500	5400	2800	4000	5300	6350	7200
3½"	1600	2100	1790	2300	2700	3300	2600	3800	4400	5100	3000	4600	5600	6600	3500	5000	6600	7800	9000
4"	1830	2450	2000	2650	3200	3800	3000	4400	5000	5700	3350	5200	6400	7600	4000	5700	7500	9000	1000
5"	3600	4800	4000	5200	6200	7600	6000	8600	10000	11300	6700	10300	12700	15000	7900	11300	15000	17900	20300
6"	4200	5500	4600	6100	7300	8900	7000	10000	11500	13500	8000	12000	14800	17400	9300	13000	17000	20700	23500

TABLE NO. 10 — STEAM Capacities in Lbs. Per Hour
MHR Valve Body No. V578A — Assembly Nos. V054, K0901

VALVE SIZE	INLET GAGE PRESSURE 2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.				
DIFFERENTIAL PRESSURE	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15	25
½"	48	63	53	70	83	100	80	120	135	155	90	140	175	210	105	155	210	240	280
¾"	85	107	98	125	148	178	142	215	240	275	160	250	310	375	188	275	375	430	500
1"	115	154	134	170	205	245	195	290	325	370	220	340	430	510	250	370	510	580	680
1¼"	163	210	180	235	280	340	270	390	450	530	310	480	580	680	350	530	680	810	920
1½"	210	270	230	300	360	440	350	510	570	680	390	620	740	870	460	680	870	1040	1200
2"	300	400	335	440	530	640	510	740	840	990	570	910	1080	1280	660	990	1280	1520	1710
2½"	430	570	470	620	750	920	720	1050	1200	1400	800	1250	1550	1800	950	1400	1800	2150	2450
3"	570	750	620	810	970	1190	920	1320	1500	1760	1010	1650	1980	2370	1210	1760	2370	2800	3170

TABLE NO. 11 — Pilot Operated Valves
MHR Valve Body Nos.: V58A, V58B, V58C (Pilot Operated) — STEAM Capacities in Lbs. Per Hour (Belfield FB) — Assembly Nos.: K202A, K202B, K202C

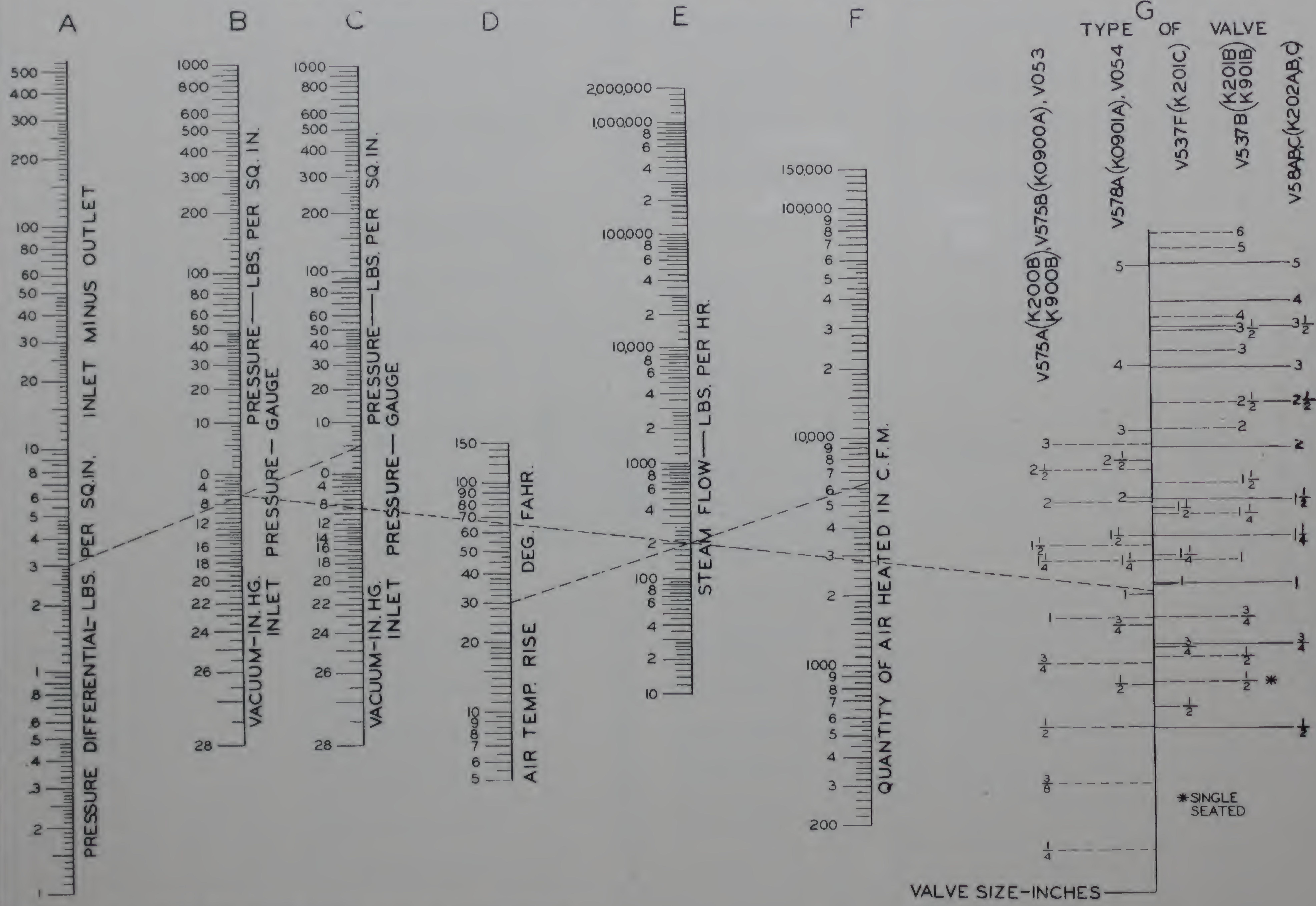
VALVE SIZE	INLET GAGE PRESSURE 2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.			
DIFFERENTIAL PRESSURE	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15
½"	30	42	32	45	54	70	49	70	93	110	54	95	125	140	62	100	140	165
¾"	65	95	71	105	130	155	115	170	200	240	125	200	270	300	140	225	300	370
1"	125	170	131	180	225	285	200	320	355	420	225	370	475	550	250	390	550	650
1¼"	190	275	200	295	350	450	320	500	560	650	350	580	740	850	395	600	850	1060
1½"	275	390	295	420	505	640	460	700	800	970	500	800	1100	1300	550	900	1300	1500
2"	460	650	500	700	850	1100	775	1295	1440	1600	810	1450	1800	2100	955	1500	2100	2600
2½"	695	1000	745	1100	1350	1650	1250	1860	2200	2500	1350	2200	2800	3200	1470	2450	3200	3900
3"	1050	1500	1150	1600	1900	2500	1750	2750	3100	3700	1900	3200	4050	4700	2200	3500	4700	5800
3½"	1440	2000	1500	2250	2700	3400	2500	3800	4250	4900	2700	4400	5700	6500	2950	4600	6700	8000
4"	1900	2750	2000	2900	3600	4500	3300	5000	5800	6900	3500	6000	7950	8800	4000	6500	8800	10700
5"	3000	4200	3200	4500	5050	6400	5000	7300	9000	10300	5500	9400	12000	13800	6300	9900	13800	16900
6"	4100	6000	4400	6500	8000	9800	7500	......	......	......	......	......	......	......	......	......	......	......

For 5-lb. gage a 2-lb. pressure drop and for 2-lb. gage a 1-lb. pressure drop may be assumed in normal cases. When valves are close to the source of supply, higher pressure drops may be expected. Allowances for special conditions should always be made in assuming pressure drops.
Whenever possible, the actual pressure drop should be measured or computed and valves sized accordingly.

TABLE NO. 12 — STEAM Capacities in Lbs. Per Hour
Packless Radiator Type Valves — Assembly Nos. V205 and V605

VALVE SIZE	VALVE STYLE	INLET GAGE PRESSURE 2 Lbs.		5 Lbs.				10 Lbs.				15 Lbs.				25 Lbs.			
	DIFFERENTIAL PRESSURE	1	2	1	2	3	5	2	5	7	10	2	6	10	15	2	5	10	15
¾"	Straight Thru	66	92	73	100	115	145	110	165	190	220	125	200	240	280	150	220	290	340
1"	Straight Thru	110	150	125	165	200	245	195	280	320	375	220	340	410	500	......	......	......	......
1¼"	Straight Thru	140	180	150	200	240	300	230	330	375	450	260	400	500	580	......	......	......	......
1½"	Straight Thru	220	295	240	320	375	460	370	540	610	700	......	......	......	......	......	......	......	......
2"	Straight Thru	360	480	400	525	625	760	600	800	1000	1150	......	......	......	......	......	......	......	......
¾"	Angle	85	110	93	125	150	185	140	210	240	280	160	260	310	375	190	280	370	440
1"	Angle	170	225	190	245	300	370	280	420	475	550	320	510	620	710	......	......	......	......
1¼"	Angle	180	240	200	260	310	380	300	440	500	580	340	530	650	750	......	......	......	......
1½"	Angle	300	400	330	440	525	650	510	750	850	975	......	......	......	......	......	......	......	......
2"	Angle	450	620	520	660	800	975	760	1100	1275	1440	......	......	......	......	......	......	......	......

STEAM CAPACITY CHART
FOR DETERMINING CAPACITY OF STANDARD MOTOR VALVE ASSEMBLIES



To determine size of body, when the known values are inlet pressure and outlet pressure:

1. Locate given weight of saturated steam on Scale "E". (In the case of a heating coil of a fan system where the quantity of steam is not known: a. Locate temperature rise of air through the coil on scale "D" b. Locate quantity of air in cu. ft. per minute passing through the coil on scale "F", c. Draw a straight line between these two points and read weight of steam on scale "E".)
2. Locate differential pressure (inlet minus outlet) on Scale "A" and locate inlet pressure on Scale "C". Draw a line between these two points and read corrected pressure on Scale "B".

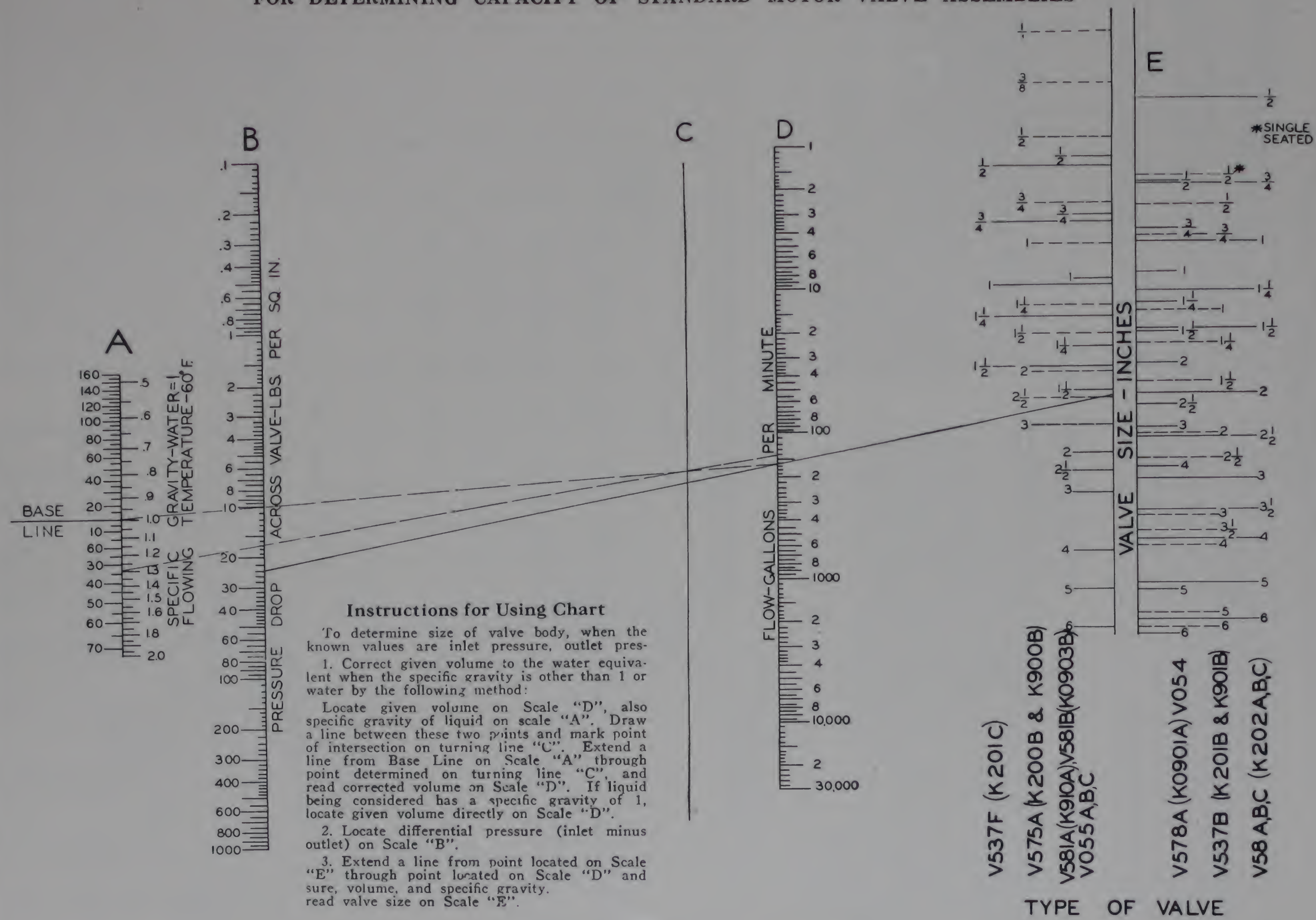
Note: If corrected pressure found on Scale "B" is a greater value than the inlet pressure previously located on Scale "C", omit use of Scales "A" and "C" and locate inlet pressure on Scale "B", working directly from that point, disregarding the differential pressure.

3. Extend a line from point located on Scale "B" through point located on Scale "E", and read the valve size on Scale "G"

M-H ENGINEERING DATA

LIQUID CAPACITY CHART

FOR DETERMINING CAPACITY OF STANDARD MOTOR VALVE ASSEMBLIES



Instructions for Using Chart

To determine size of valve body, when the known values are inlet pressure, outlet pressure, volume, and specific gravity.

1. Correct given volume to the water equivalent when the specific gravity is other than 1 or water by the following method:

Locate given volume on Scale "D", also specific gravity of liquid on scale "A". Draw a line between these two points and mark point of intersection on turning line "C". Extend a line from Base Line on Scale "A" through point determined on turning line "C", and read corrected volume on Scale "D". If liquid being considered has a specific gravity of 1, locate given volume directly on Scale "D".

2. Locate differential pressure (inlet minus outlet) on Scale "B".

3. Extend a line from point located on Scale "E" through point located on Scale "D" and read valve size on Scale "E".

NOTE: Refer to pages 29 thru 35 to identify valve body numbers shown above with the proper complete valve assembly.

M-H ENGINEERING DATA

VALVE BODIES

The V537F is of the bronze body type with the bronze trim. The valve seats are of the screwed insert type and are renewable. This valve is not available with any trim other than the bronze. Since it is a bevel seated non-throttling type valve, a lift coefficient table is not shown.

The 5007 or V537B has a semi-steel body with a standard trim of Duromite bronze for standard service, and a special trim of KA2 stainless steel for high pressure, high temperature service. The valve seats are of the insert type and are therefore renewable.

For brine service select a valve body of material the same as the pipe line in order to prevent electrolysis and hydrolysis with resultant deteriorating affect on the valve.

The V575A and V575B has a bronze body with bronze trim, and renewable composition discs.

VALVE TRAVEL COEFFICIENTS

The starred lifts shown on the following lift coefficient tables are the lifts which will allow the valves to pass the quantities shown in valve tables and charts.

For example: The starred lift of 3" V537B from Table No. 2 is 1½". This is considered as the normal lift of the valve and will give flow capacity as shown on Table No. 9, page 17, and the Chart on page 18. This valve, with a two-pound inlet pressure and one-pound differential, with a starred lift of 1½" will permit the flow of 1,300 pounds of steam per hour, as shown on Table No. 9. If a change in the capacity of the valve is desired, the lift, of course, must be varied.

If it is desired to reduce the capacity of this same valve to 900 pounds of steam per hour, the lift coefficient is established by dividing 900 by 1,300, which equals .692.

Next refer to coefficient Table No. 2, and for the 3" size valve follow across the table to the right until a figure close to .692 is found. In this case it will be found to be .684. The correct lift to use in order to get a flow of nearly 900 pounds per hour is then found at the top of the column as 1".

To check back, multiply 1,300 by .684 and obtain 888 pounds of steam per hour, which is close enough to 900 pounds for all practical purposes.

V575
TABLE NO 1
STEAM, AIR, GAS, AND LIQUID CHART

Valve Size in Inches	Valve Opening in Inches									Full Open position of Valve ¾ Inches
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	
½	.197	.273	.345	.409	.470	.537	.606	.690	.884	*
¾	....	....	....	. .	..	....	....	....	....	....
1	.152	.208	.266	.312	.343	.373	.426	.487	.648	*
1¼	....	....	....	....	....	....	....	....	....	....
1½	.076	.149	.208	.253	.279	.317	.361	.425	.621	*
2	....	....	....	....	....	....	....	....	....	....
2½	.119	.150	.188	.219	.250	.281	.313	.351	.532	*
3	....	....	....	....	....	....	....	....	....	....

V537B (Fisher 5007) K201B, K901B

TABLE NO. 2
STEAM, AIR, AND GAS CHART

Pipe Size of Valve, Inches	Valve Opening, Inches												
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	1	1¼	1½	2
½	.162	.312	.514	.723	.887	*	Sing	le S	eate	d			
½	.163	.336	.581	.781	.888	*	.104	....	....	....	....	....	....
¾	.141	.261	.445	.663	.867	*	1 07	....	....	....	....	....	....
1	.088	....	.321	....	.658	....	.890	*	....	....	....	....	....
1¼	.059	....	.214	....	.489	....	.809	*	1.06	....	....	....	....
1½	.027	....	.133	....	.323	....	.562	.814	*	....	....	....	....
2	....	....	.08	....	18	....	.32	....	.60	.91	*	....	....
2½	....	....	.058	....	.109	....	.186	....	.381	.608	.822	*	....
3	....	....	.057	....	.115	....	.211	....	438	.684	.890	*	....
4	....	....	.044	....	.083	....	.134	....	.31	.534	.77	*	1.24
6	....	....	.02	....	.046	....	.10	....	.27	.51	.79	*	....

TABLE NO. 3
LIQUID CHART

Pipe Size of Valve Inches	Valve Opening, Inches											
	1/8	1/4	3/8	7/16	1/2	5/8	3/4	1	1¼	1½	1¾	2
½	.168	.529	.91	*	1.05	Sing	le Se	ated				
½	.152	.588	933	*	1.04	....	....	....	....	....	....	....
¾	.14	.430	861	*	1.08	....	....	....	....	....	....	....
1	.110	.36	.717	.839	.923	*	....	....	....	....	....	....
1¼	.065	.204	.503	682	817	*	1.11	....	....	....	....	....
1½	.047	.16	35	.46	58	82	*	....	....	....	....	....
2	.03	08	.18	.24	.32	.48	.60	91	*	....	....	....
2½	.035	.063	115	147	.185	.273	379	.582	.792	*	....	....
3	018	064	.138	.178	.227	.326	.435	671	857	*	....	....
4	02	.041	089	.107	.136	.21	.3	.49	.79	*	....	....
6	0067	.0223	059	.07	105	.17	272	.51	.789	*	1.122	1.165

M-H ENGINEERING DATA

PRESSURE RATINGS—PNEUMATIC VALVES

RADIATOR VALVES

VALVE SIZE	PRESSURE RATINGS	
	4# Valve Spring	10# Valve Spring
V052B, Single Seated, 3" Tops		
½" Screwed	50	48
¾" "	36	18
1" "	18	9
V0500A, Single Seated, 4" Tops		
½" Screwed	50	50
¾" "	50	50
1" "	50	37
1¼" "	45	22
1½" "	30	15
2" "	15	7

COIL VALVES
Normally Open—Standard Tops

VALVE SIZE	PRESSURE RATINGS		
	5# Valve Spring	8# Valve Spring	12# Valve Spring
V053A, Single Seated, 4" Top			
¼" Screwed	125	125	125
⅜" "	125	125	125
½" "	125	125	106
¾" "	125	90	45
1" "	75	50	25
1¼" "	45	30	15
1½" "	30	20	10
V053B, Single Seated, 7" Top			
2" Screwed	27	18	9
2½" "	18	12	6
3" "	12	8	5
3½" Flanged	9	6	5
V053C, Single Seated, 10" Top			
4" Flanged	27	18	9
5" "	21	14	7
6" "	12	8	5
V054A, Double Seated, 4" Top			
½" Screwed	150	150	150
¾" "	150	150	150
1" "	150	150	150
1¼" "	150	150	142
1½" "	150	150	90
2" "	120	80	40
V054C, Double Seated, 7" Top			
2½" Screwed	150	140	70
3" "	150	100	50
3½" Flanged	135	90	45
V054E, Double Seated, 10" Top			
4" Flanged	120	80	40
5" "	105	70	35
6" "	90	60	30
8" "	60	40	20
10" "	30	20	10

COIL VALVES
Normally Open—Oversize Tops

VALVE SIZE	PRESSURE RATINGS		
	5# Valve Spring	8# Valve Spring	12# Valve Spring
V053B, Single Seated, 7" Top			
½" Screwed	125	125	125
¾" "	125	125	70
1" "	125	84	42
1¼" "	75	50	25
1½" "	48	30	18
V053C, Single Seated, 10" Top			
2" Screwed	105	70	35
2½" "	63	42	21
3" "	45	30	15
3½" Flanged	33	22	11

COIL VALVES
Normally Closed—Standard Tops

VALVE SIZE	PRESSURE RATINGS		
	5# Valve Spring	8# Valve Spring	12# Valve Spring
V053E, Single Seated, 4" Top			
½" Screwed			90
¾" "			90
1" "			50
1¼" "			30
V054B, Double Seated, 4" Top			
½" Screwed	150	150	150
¾" "	150	150	150
1" "	150	150	150
1¼" "	125	150	150
1½" "	90	150	150
2" "	40	80	120
V054D, Double Seated, 7" Top			
2½" Screwed	70	140	150
3" "	50	100	150
3½" Flanged	45	90	135
V054F, Double Seated, 10" Top			
4" Flanged	40	80	120
5" "	35	70	105
6" "	30	60	90

COIL VALVES
Normally Closed—Oversize Tops

VALVE SIZE	PRESSURE RATINGS
	12# Valve Spring
V053F, Single Seated, 7" Top	
½" Screwed	125
¾" "	125
1" "	100
1¼" "	60
1½" "	45
2" "	35

GRAD-U-TROL VALVES

VALVE SIZE	PRESSURE RATING	
	K0900A	K0901A
¼"	125	——
⅜"	125	——
½"	125	150
¾"	125	150
1"	100	150
1¼"	65	150
1½"	45	150
2"	25	150
2½"	15	125
3"	10	125

THREE-WAY MIXING VALVES
Standard Tops

VALVE SIZE	PRESSURE RATING Unbalanced Pressure
V055A, 4" Top	
½" Screwed	60
¾" "	60
1" "	37
1¼" "	23
1½" "	16
2" "	9
V055B, 7" Top	
2½" Screwed	12
3" "	8
V055C, 10" Top	
4" Flanged	18
5" "	14
6" "	8

THREE-WAY MIXING VALVES
Oversize Tops

VALVE SIZE	PRESSURE RATING Unbalanced Pressure
V055B, 7" Top	
½" Screwed	60
¾" "	60
1" "	60
1¼" "	60
1½" "	40
2" "	24
V055C, 10" Top	
2½" Screwed	42
3" "	30

(1) These maximum pressure ratings are based upon a minimum of 15 lbs. in the branch line to the valve when the leakport of the controller is closed off.

(2) The pressure rating for Three-Way Mixing Valves is the **unbalanced pressure** between the two inlets to the valve. The valve bodies are rated at 125 lbs. See page 37 for Pressure Rating of K0903B.

M-H ENGINEERING DATA
PRESSURE RATINGS—MOTORIZED VALVES

M204 and M904 Modutrol Motors with Q601B Linkage
M-H-R V575A (Installed with pressure over the seat) K200 and K900

Valve Size	PRESSURE RATINGS		
	30-Second Motor	60-Second Motor	120-Second Motor
¼", ⅜" & ½"	125	125	125
¾"	125	125	125
1"	115	125	125
1¼"	75	105	105
1½"	55	75	75
2"	30	45	45
2½"	18	25	25
3"	12	15	15

Maximum Static Pressure=125 lbs.

M204 and M904 Modutrol Motors with Q601B Linkage.
M-H-R V575A (Installed with pressure under the seat) K200 and K900

Valve Size	PRESSURE RATINGS		
	30-Second Motor	60-Second Motor	120-Second Motor
¼", ⅜" & ½"	125	125	125
¾"	125	125	125
1"	75	85	85
1¼"	50	60	60
1½"	35	40	40
2"	20	25	25
2½"	13	15	15
3"	8.5	10	10

Maximum Static Pressure=125 lbs.

M-H-R V537B, (Fisher 5007) M-H-R V537F* K201C, K201B, K901B

Valve Size	PRESSURE RATINGS		
	30-Second Motor	60-Second Motor	120-Second Motor
½"	150	150	150
¾"	150	150	150
1"	150	150	150
1¼"	150	150	150
1½"	150	150	150
2"	125	150	150
2½"	100	150	150
3"	75	145	145
3½"	65	125	125
4"	55	105	105
5"	18	65	80
6"	14	60	75

Maximum Static Pressure = 150 lbs. Screwed.
Maximum Static Pressure = 125 lbs. Flanged.

*V537F, available only in sizes ½" thru 1½".

M-H-R V581A (Maximum Static Pressure—125 lbs.) K910A

Valve Size	PRESSURE RATINGS	
	60-Second Motor	120-Second Motor
½"	60	60
¾"	60	60
1"	60	60
1¼"	60	60
1½"	40	40
2"	25	25

Maximum Static Pressure=125 lbs.

M-H ENGINEERING DATA

PRESSURE RATINGS—MOTORIZED VALVES

M-H-R V538B (Belfield 3922) K203A, K903A

Valve Size	PRESSURE RATINGS		
	30-Second Motor	60-Second Motor	120-Second Motor
½″	150	150	150
¾″	150	150	150
1″	90	90	90
1¼″	50	60	60
1½″	25	40	40
2″	13	25	25
2½″	7	16	16
3″	3	8	11
3½″	2	6	8
4″	1.5	4	6

Maximum Static Pressure=125 lbs.—flanged pattern—2″ to 4″ size.
150 lbs.—screwed pattern—½″ to 3″ size.

M-H-R V58A, V58B, V58C **Belfield Type FB** K202A, K202B, K202C

Valve Size	PRESSURE RATINGS		
	30-Second Motor	60-Second Motor	120-Second Motor
½″	150	150	150
¾″	150	150	150
1″	150	150	150
1¼″	150	150	150
1½″	150	150	150
2″	150	150	150
2½″	150	150	150
3″	150	150	150
3½″	125	125	125
4″	125	125	125
5″	100	125	125
6″	45	125	125

Maximum Static Pressure=150 lbs.

THREE-WAY VALVES

A three-way valve is usually applied to control the flow of liquids. It may be installed to operate as a diverting valve or as a mixing valve, and the only difference is in the piping arrangement.

If used as a diverting valve, the valve is piped so that the fluid enters through one connection to the valve and leaves through one or both of the other two, depending upon the position of the inner valve. In other words, a diverting valve is connected with one inlet and two outlets, and the valve is used to divert the entering liquid through one of the two outlets. Figure No. 1 shows the internal construction of a three-way valve and a diverting valve would be connected so that the liquid enters at "A" and leaves through either "B" or "C", depending upon the position of the disc.

If a three-way valve is piped to operate as a mixing valve, fluid from two separate sources enters the valve at two connections and leaves the valve at the third connection. Depending upon the position of the valve disc, fluid is mixed in the valve in various proportions from the two inlets and leaves through the outlet. A mixing valve is always used to blend or mix fluids from two separate sources and discharge the mixture into a third line. In Figure No. 1 the valve would be piped for mixing application with the discharge from "A" and the two inlets connected at "B" or "C".

MIXING VALVES

All pressure ratings for three-way valves given in the control manual apply if the valve is used as a mixing valve. Pressure ratings on three-way valves refer to the maximum unbalanced condition that may exist across the valve. In determining the required pressure rating on a three-way valve for a given application the maximum pressure difference that can exist between the two inlet connections must be known. If the valve shown in Figure No. 1 is connected as a mixing valve, the pressures on the two inlet connections might be 90 lbs. per square inch at "B" and 70 lbs. per square inch at "C". The pressure difference is 20 lbs. per square in. and if the valve size is 2 inch, it may be determined from the pressure rating tables for the K203A that a 60 second or slower timing motor will be satisfactory since the rating for a 60 second motor is 25 lbs. per square inch.

If under the above pressure conditions the disc in the valve shown in Figure No. 1 is either up or down, the pressure difference "C"-"B" is 20 lbs. per square inch. The pressure difference "C"-"A" or "B"-"A" is equal only to the pressure drop through the valve, regardless of disc position. This pressure drop depends upon flow through the valve and is usually relatively low. In a mixing valve the force exerted on the valve disc due to the unbalanced pressure at the two inlets is always in one direction for a given piping arrangement. In the example above with 90 lbs. at "B" and 70 lbs. at "C" the 20 lb. differential pressure will always tend to push the valve disc upward.

DIVERTING VALVES

If the valve in Figure No. 1 is used as a diverting valve, the liquid would enter at "A" and leave through either "B" or "C", depending upon disc position. Assume that the liquid entering at "A" is at 20 lbs. per square inch pressure and that "B" is connected to discharge the liquid to atmosphere while "C" is connected to a tank under a constant pressure of 10 lbs. per square inch. Actually the pressure difference across any two valve connections is 20 lbs. "A"-"B" and 10 lbs. "A"-"C". Pressure rating tables for three-way valves would indicate that if a 2 inch valve is required, a motor with 60 second timing or slower will operate the valve satisfactorily. **This is not true,** and pressure rating tables for three-way valves do not apply to three-way valves used as diverting valves.

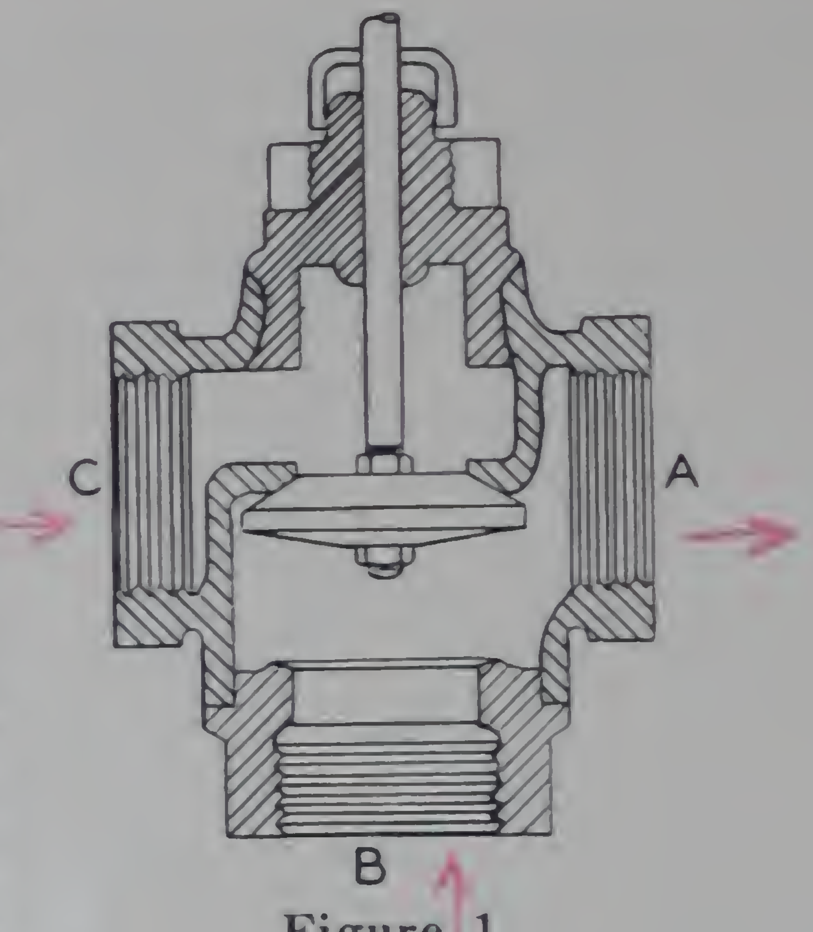


Figure 1

The reason for this is that in a diverting valve the unbalanced pressure across the valve connections does not exert force on the valve disc in the same direction for all positions of the disc. In the example above, if the valve disc in Figure No. 1 is down and assuming that the area of the disc is two sq. in. there would be a force of 40 lbs. tending to hold the disc down against the lower seat. If the disc is up, there would be a force of 20 lbs. in the opposite direction tending to hold the disc up against the upper disc.

If the valve disc is down against the lower seat and starts to move upward toward the upper seat, the pressure exerted on the disc transfers from a downward pressure to an upward pressure throughout the stroke of the valve. However, at some critical position of the disc, usually near the upper or lower seats, this pressure transfer is quite rapid and in some cases almost instantaneous. This rapid transfer of force, if the force is large enough, will overcome the strain release in an electric valve or the spring and diaphragm balance in a pneumatic valve and the disc will slap or bounce against the seat, causing water hammer. Most of the difficulty with diverting valves is caused by this condition.

A three-way valve may be used as a diverting valve if the pressure on all three connections is practically the same for all positions of the valve disc. Actually, such conditions rarely exist, which is the reason for our general recommendation that our three-way valves be used as mixing valves only. For diverting valve applications, it is recommended that two globe valves be used in place of one three-way valve. Also, if pressure differences are higher than the ratings for three-way valves used as mixing valves, two globe valves should be used.

APPLICATIONS

Figure No. 2 and Figure No. 3 represent two very common installations using three-way valves. Figure No. 2 represents the installation of a three-way valve on a coil to cause the liquid to circulate through the coil or bypass the coil. Either hookup will accomplish the desired results. The valve is applied as a diverting valve in Figure No. 2A and as a mixing valve in Figure No. 2B. Installations of this type should always be made as shown in Figure No. 2B so that the valve will have two inlets and one outlet and operate as a mixing valve.

Figure No. 3 illustrates the same hookup as in Figure No. 2 except as applied to an air washer. The valve should be installed as shown in Figure 3B to operate as a mixing valve.

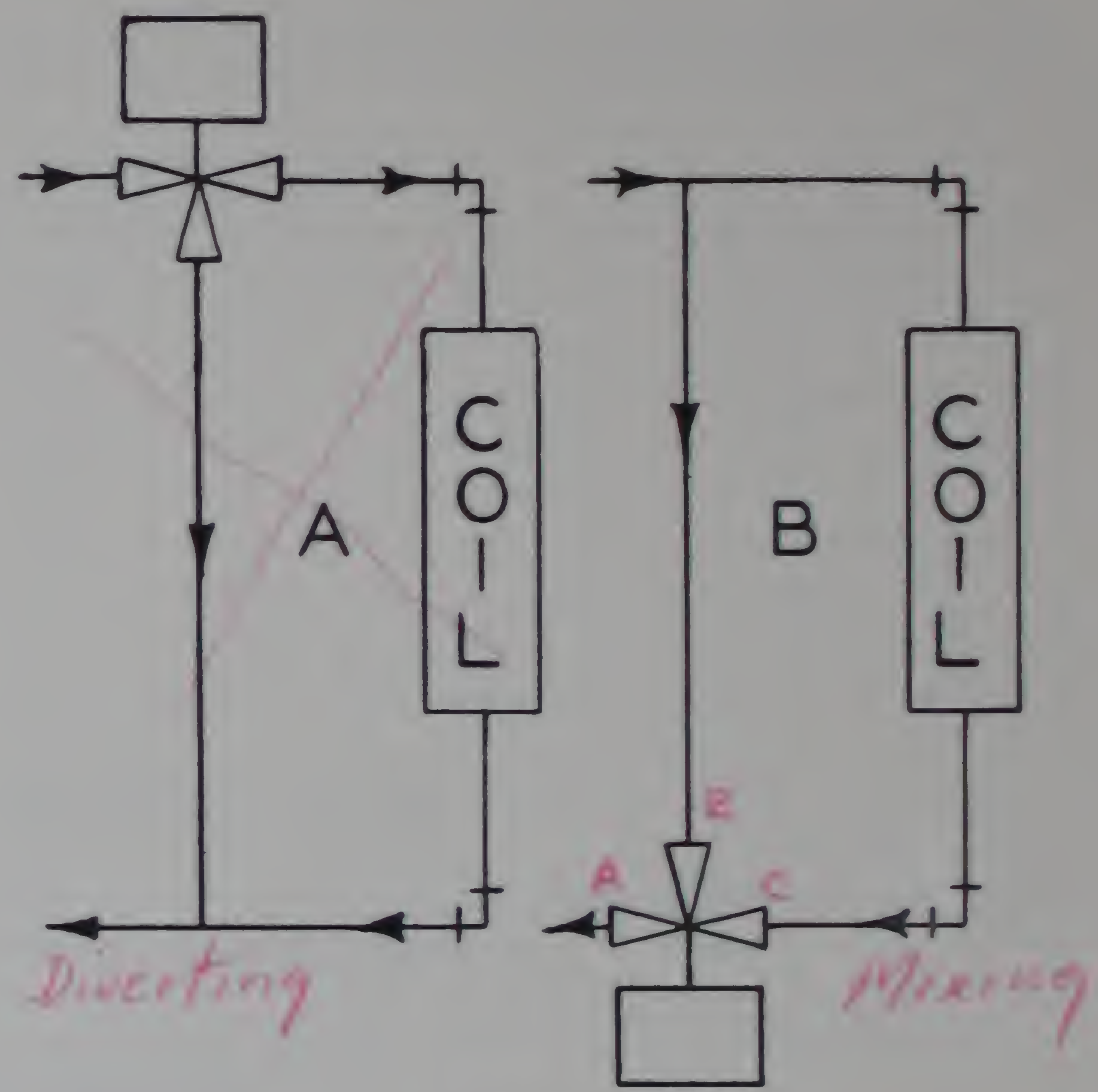


Figure 2

It is extremely important to connect the piping properly to a three-way valve. The V581A and V581B three-way mixing valve bodies used in the K910A and K0903B valve assemblies are suitable only for mixing valve service and are stamped with an arrow near the common pipe connection to show flow toward the outlet (common) pipe connection.

Each pipe connection of the V538B valve is marked with the letters A, B or C as shown in Figure 1. The letter A identifies the common pipe connection, which is the outlet on a mixing valve and the inlet on a diverting valve.

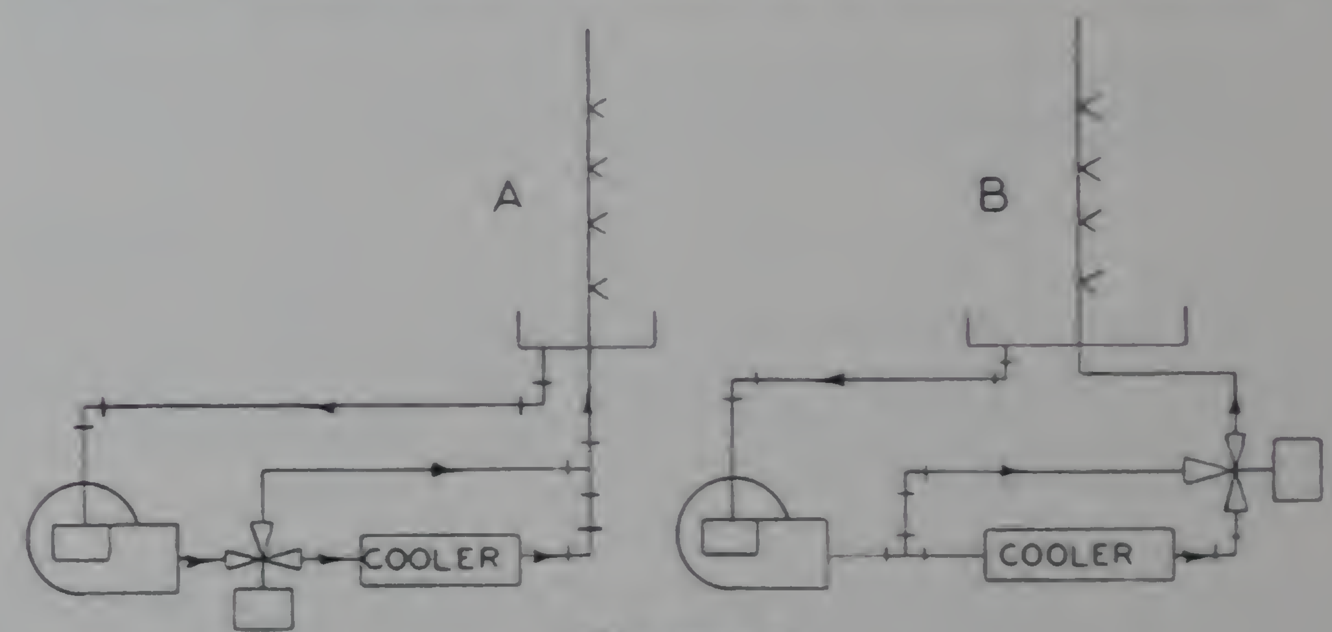


Figure 3

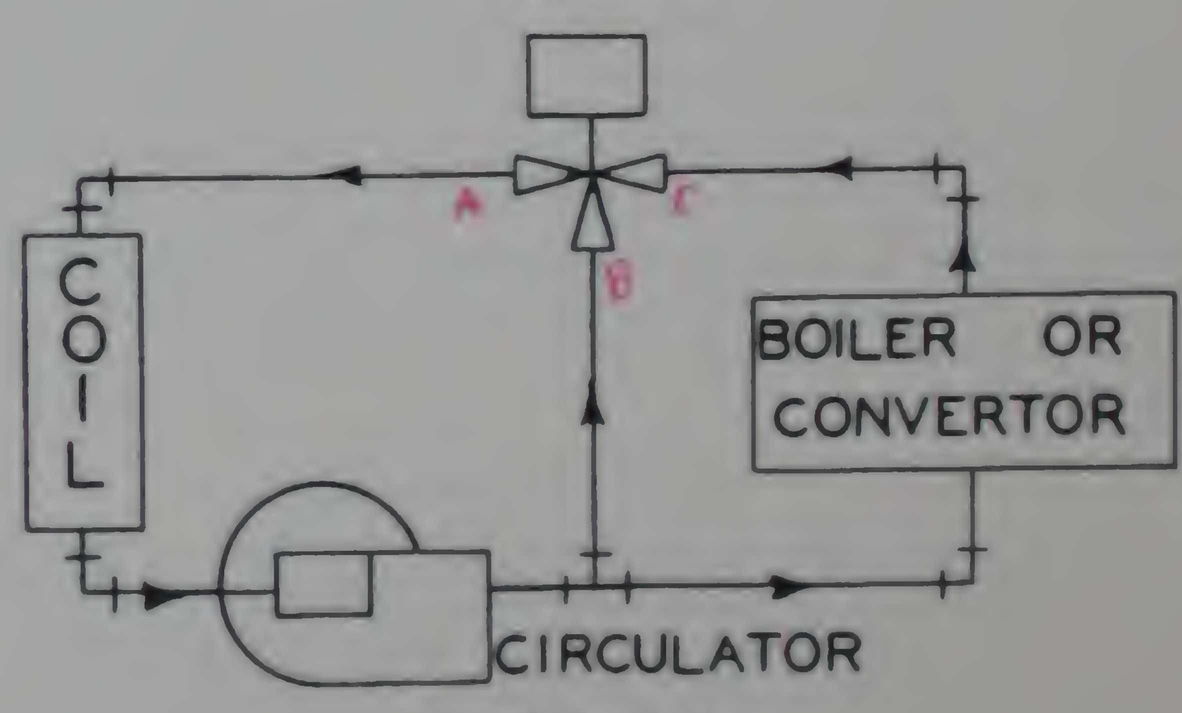


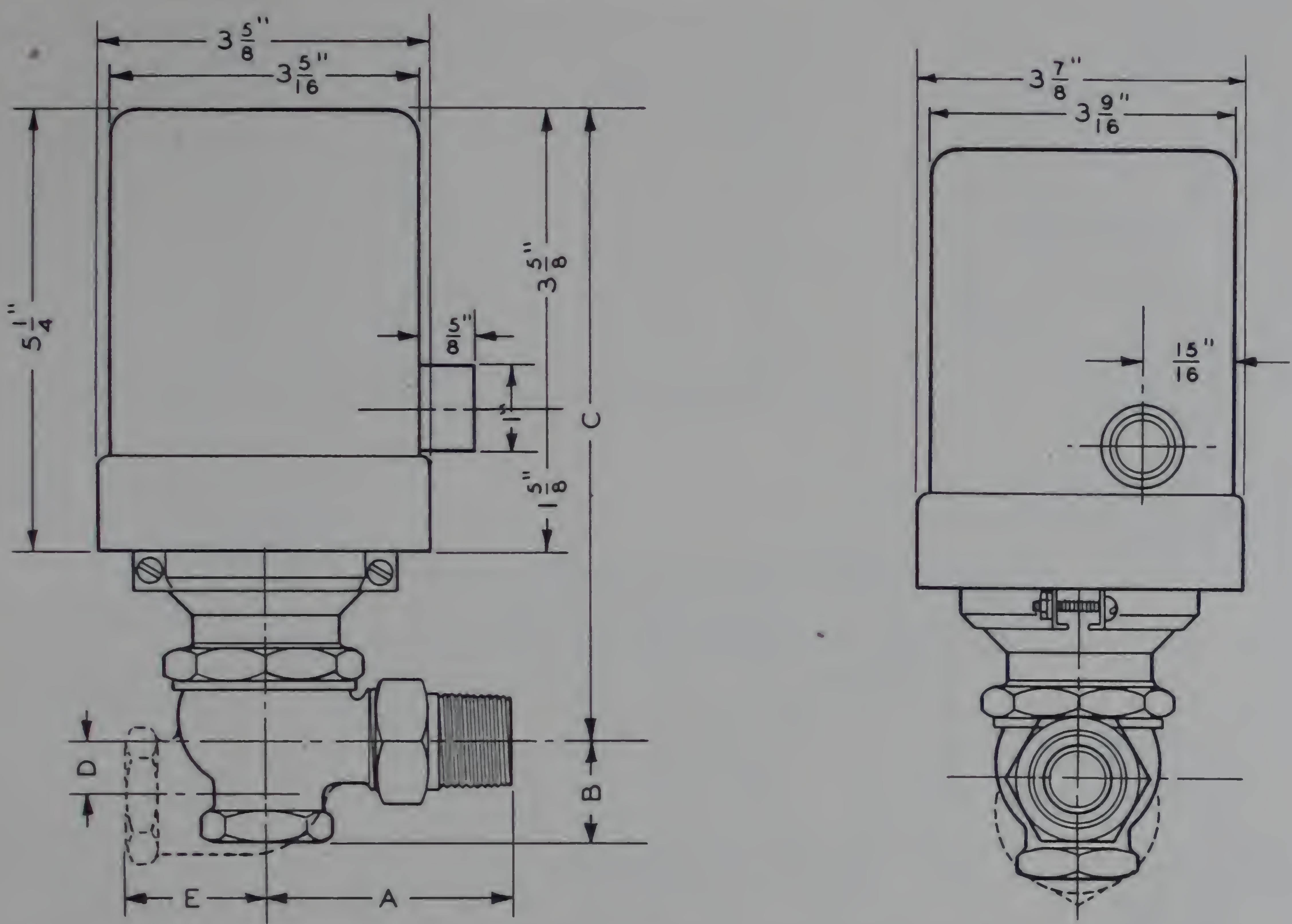
Figure 4

Hook-up showing schematic arrangement of equipment and piping for a three-way mixing valve to allow constant circulation of water thru coil at all times when circulator is running.

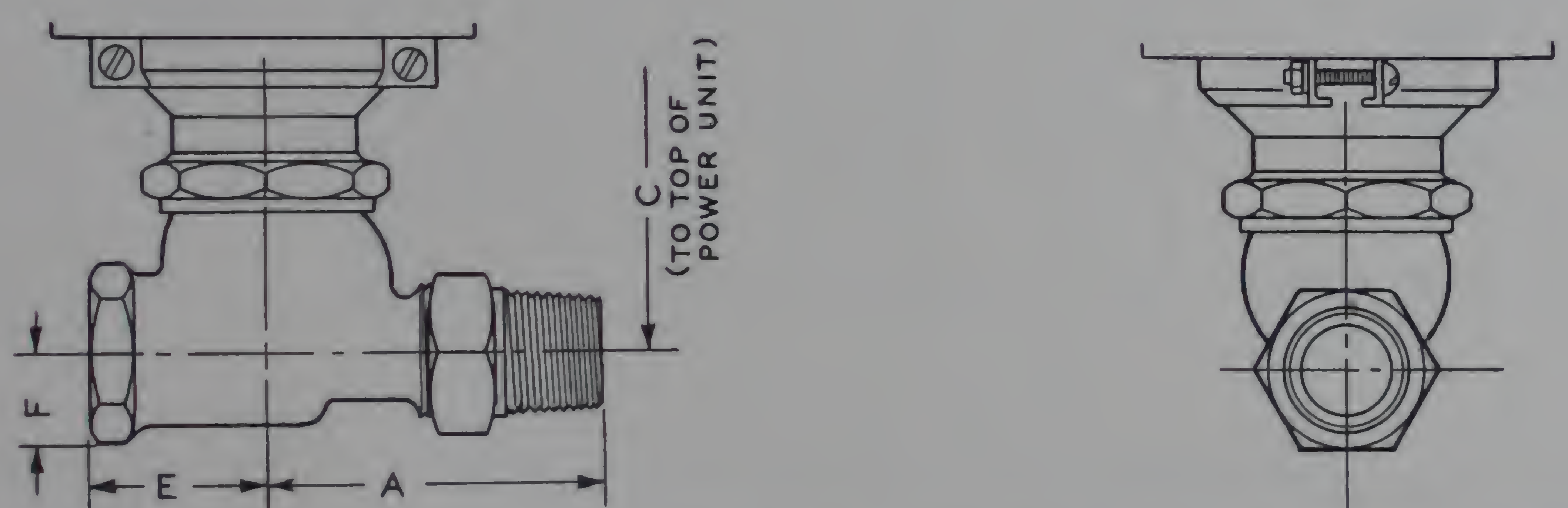
M-H ENGINEERING DATA

ELECTRIC RADIATOR VALVES

Types V205 and V605



V205A and V605A with angle body (dotted lines show straight-through offset body).



V205A and V605A with straight-through non-offset body. (See figure above for power unit dimensions).

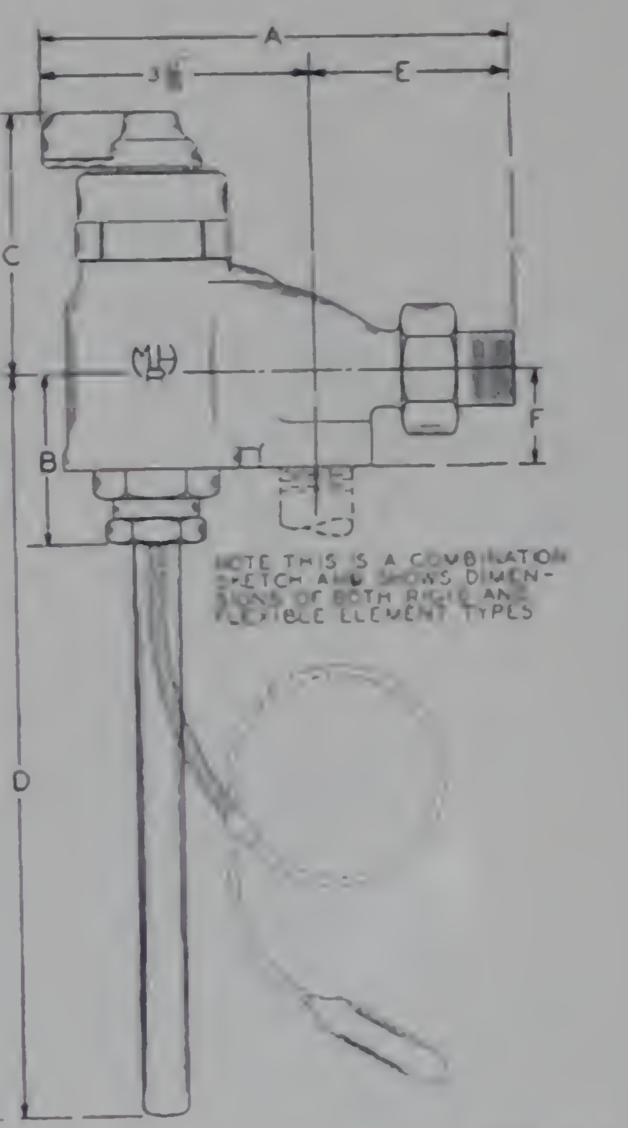
ANGLE VALVE BODY			
Size	A	B	C
3/4"	3 1/16"	1 3/16"	7 9/16"
1"	3 1/8"	1 1/2"	7 3/8"
1 1/4"	3 1/2"	1 5/8"	7 11/32"
1 1/2"	3 3/4"	1 7/8"	7 3/4"
2"	4 3/8"	2 1/4"	8 5/32"

STRAIGHT THROUGH OFFSET VALVE BODY				
Size	A	C	D	E
3/4"	3 1/16"	7 9/16"	3/4"	1 5/8"
1"	3 1/8"	7 3/8"	1"	1 7/8"
1 1/4"	3 1/2"	7 11/32"	1 1/8"	2 1/16"
1 1/2"	3 3/4"	7 3/4"	1 1/4"	2 5/16"
2"	4 3/8"	8 5/32"	1 1/2"	2 11/16"

STRAIGHT THROUGH NON-OFFSET VALVE BODY				
Size	A	E	F	C
3/4"	3 1/8"	1 5/8"	27/32"	7 9/32"
1"	3 5/8"	1 7/8"	1"	5 3/8"
1 1/4"	3 7/8"	2 1/16"	1 7/32"	8 7/16"
1 1/2"	4 1/2"	2 5/16"	1 5/16"	9"
2"	5 13/32"	2 11/16"	1 19/32"	9 5/8"

M-H ENGINEERING DATA

THE MODUSTAT
Types V505A and V506A



Dimension	MODUSTAT SIZE		
	½″	¾″	1″
A	6 7/16	6 7/16	6 13/16
B	2 1/4	2 1/4	3 7/32
C	3 9/16	3 9/16	2 13/16
D	10 1/8	10 1/8	10 13/16
E	2 3/4	2 3/4	3 1/8
F	1 13/32	1 5/16	2 1/2

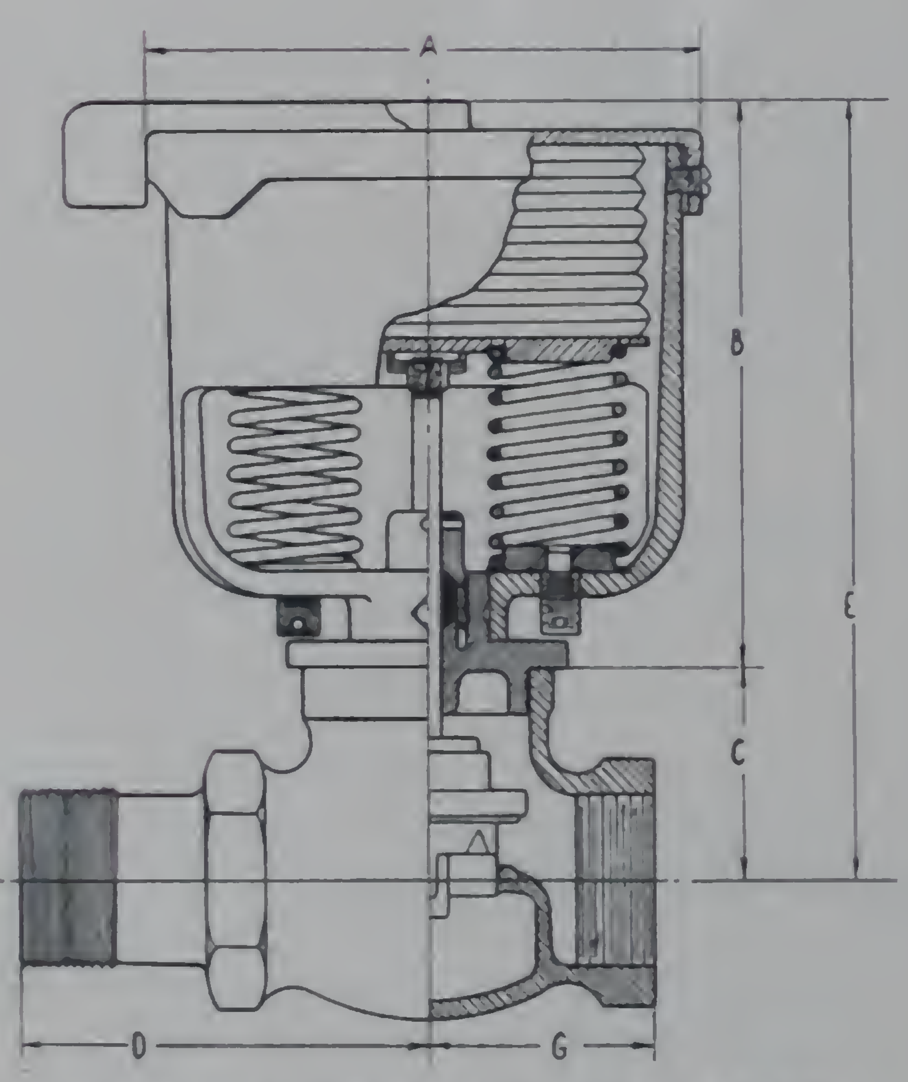
PNEUMATIC UNIT VENTILATOR VALVES

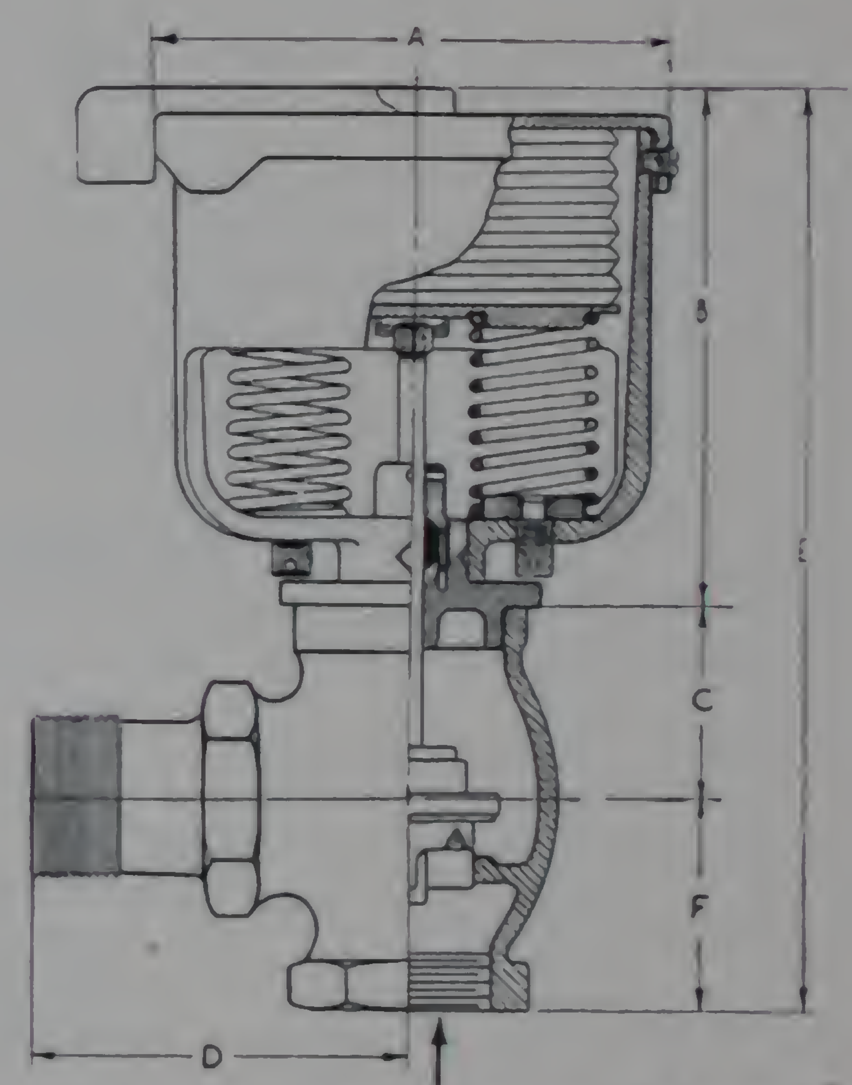
Type V056A Angle

Valve Size	¾″	1″	1-1¼″	1-1½″	2″
A	5	5	5	5	5
B	5 3/16	5 7/32	5 7/32	5 7/32	5 7/32
C	27/32	1	1 1/8	1 7/16	1 11/16
D	2 7/8	3 1/8	3 9/16	3 3/4	4 5/16
E	7 11/32	7 23/32	8 3/32	8 21/32	9 5/32
F	1 5/16	1 1/2	1 3/4	2	2 1/4

Type V056A St. Thru

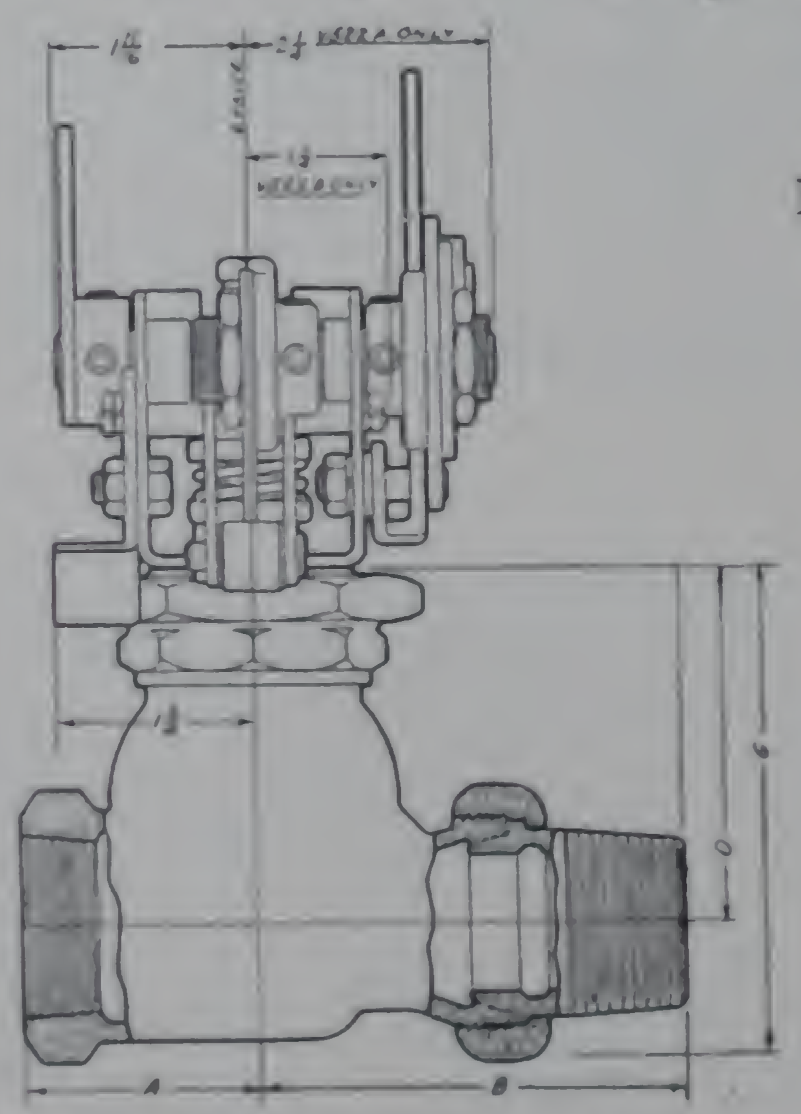
Valve Size	¾″	1″	1-¼″	1-½″	2″
A	5	5	5	5	5
B	5 3/16	5 7/32	5 7/32	5 7/32	5 7/32
C	1 1/4	1 9/16	1 13/16	2	2 5/16
D	2 15/16	3 3/16	3 5/8	3 15/16	4 3/8
E	6 7/16	6 25/32	7 1/32	7 7/32	7 17/32
G	1 5/8	1 3/4	2	2 1/4	2 9/16

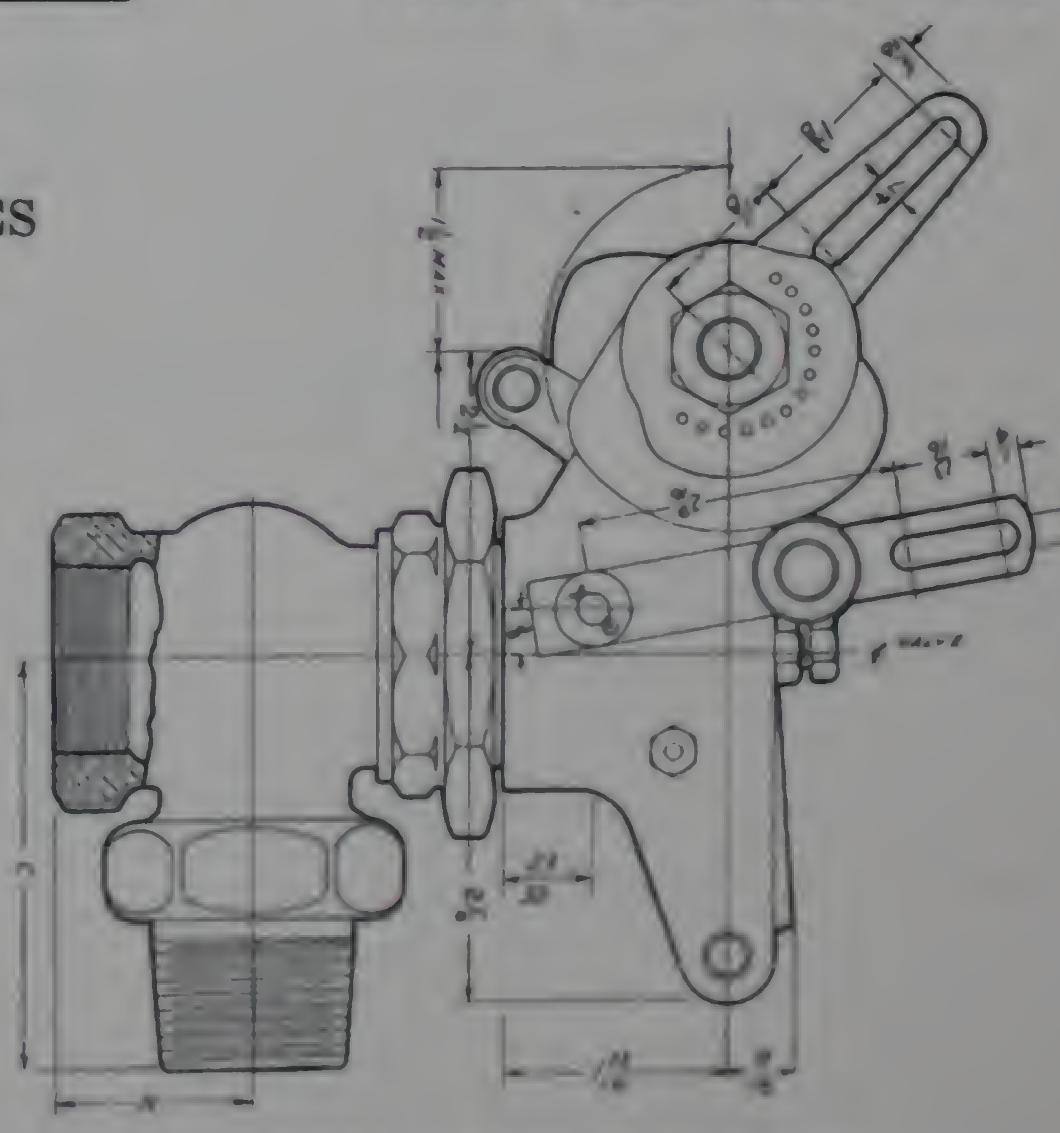

V056A Straight-through Valve


V056A Angle Type Valve

ELECTRIC UNIT VENTILATOR VALVES
Types V522A and V522B

Valve Size	¾″	1″	1¼
A	1 9/16	1 7/8	2 1/16
B	2 7/8	3 5/16	3 15/16
C	2 3/4	3	3 9/16
D	2 13/16	3 1/16	3 1/8
E	2 1/16	2 1/16	2
G	3 3/4	4 1/16	4 3/8
H	1 3/16	1 1/2	1 3/4


V522 Straight-through Valve
(End View of upper valve)


V522 Angle Type Valve
(Side View of upper valve)

M-H ENGINEERING DATA

PNEUMATIC RADIATOR VALVES

Type V0500A

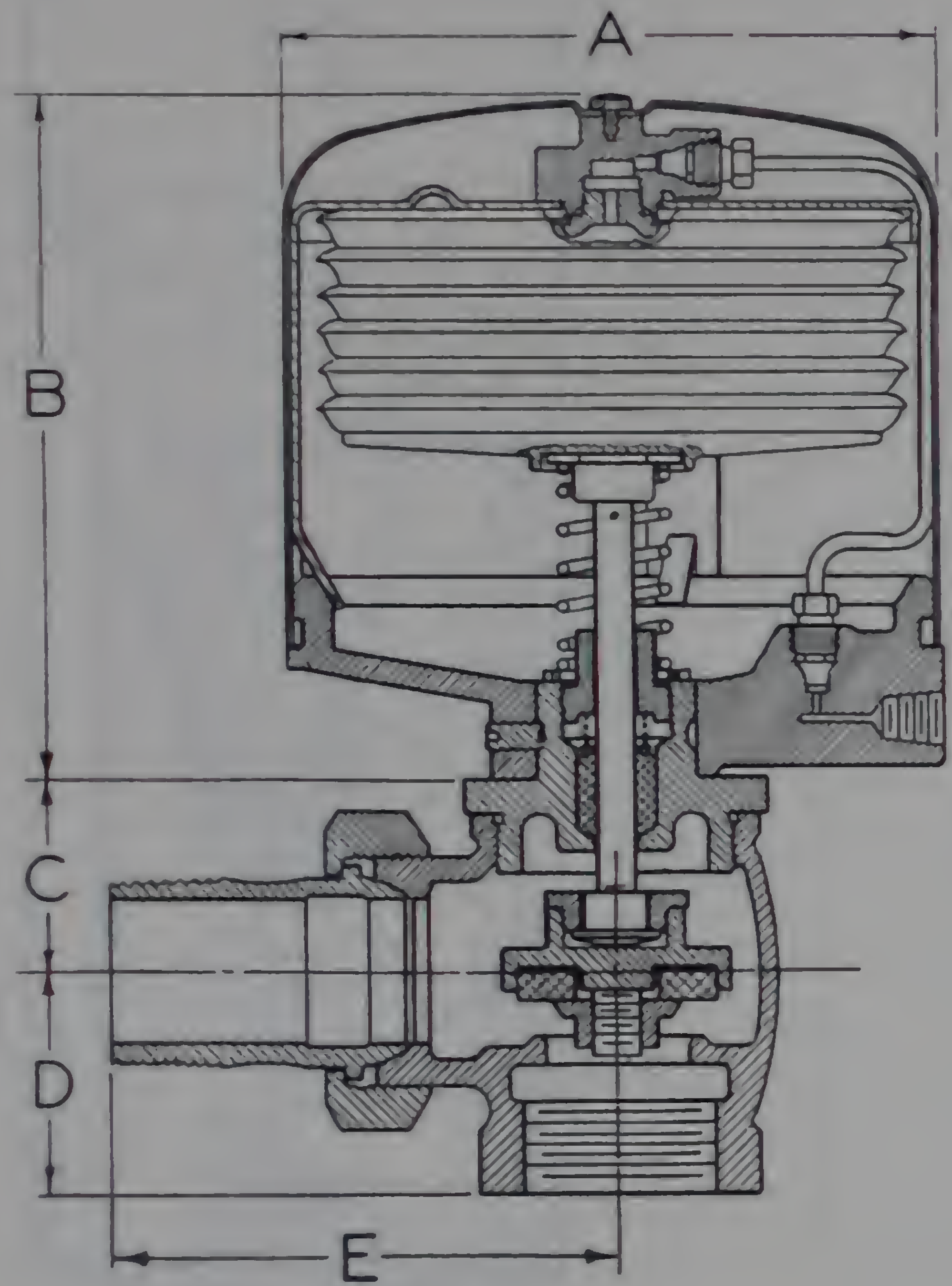


Figure 1
Angle Valve

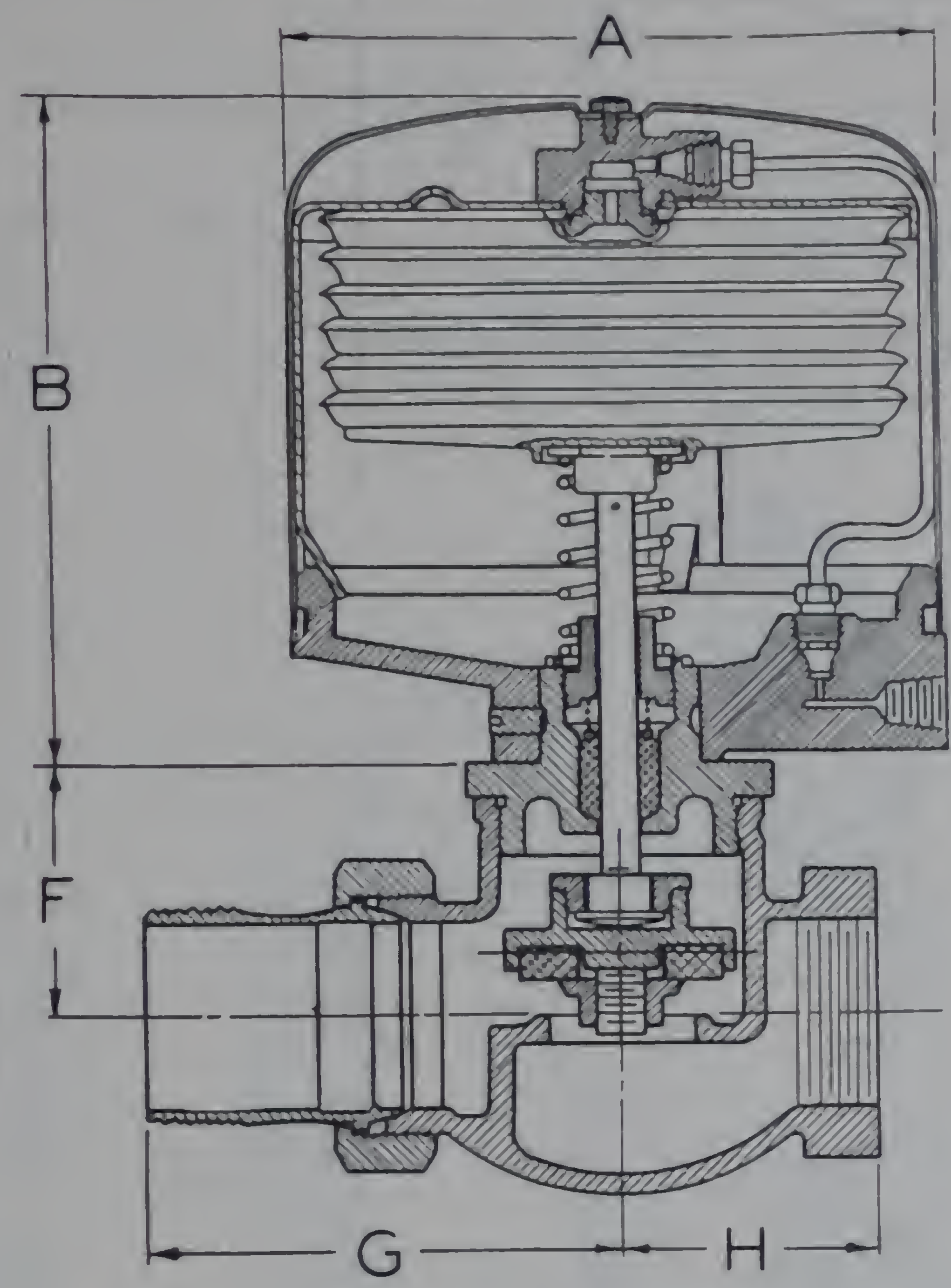


Figure 2
Globe Valve with Union

Valve Size	ROUGHING-IN DIMENSIONS							
	A	B	C	D	E	F	G	H
½″	4 5/16	4 9/16	1 7/32	1 1/8	2 13/16	1 19/32	2 13/16	1 5/16
¾″	4 5/16	4 9/16	1 1/16	1 5/16	2 7/8	1 15/32	2 15/16	1 5/8
1″	4 5/16	4 9/16	1 1/4	1 1/2	3 1/8	1 13/16	3 3/16	1 3/4
1¼″	4 5/16	4 9/16	1 3/8	1 3/4	3 9/16	2 1/16	3 5/8	2
1½″	4 5/16	4 9/16	1 11/16	2	3 3/4	2 1/4	3 15/16	2 1/4
2″	4 5/16	4 9/16	1 15/16	2 1/4	4 5/16	2 9/16	4 3/8	2 9/16

V0500A—Radiator Valves.

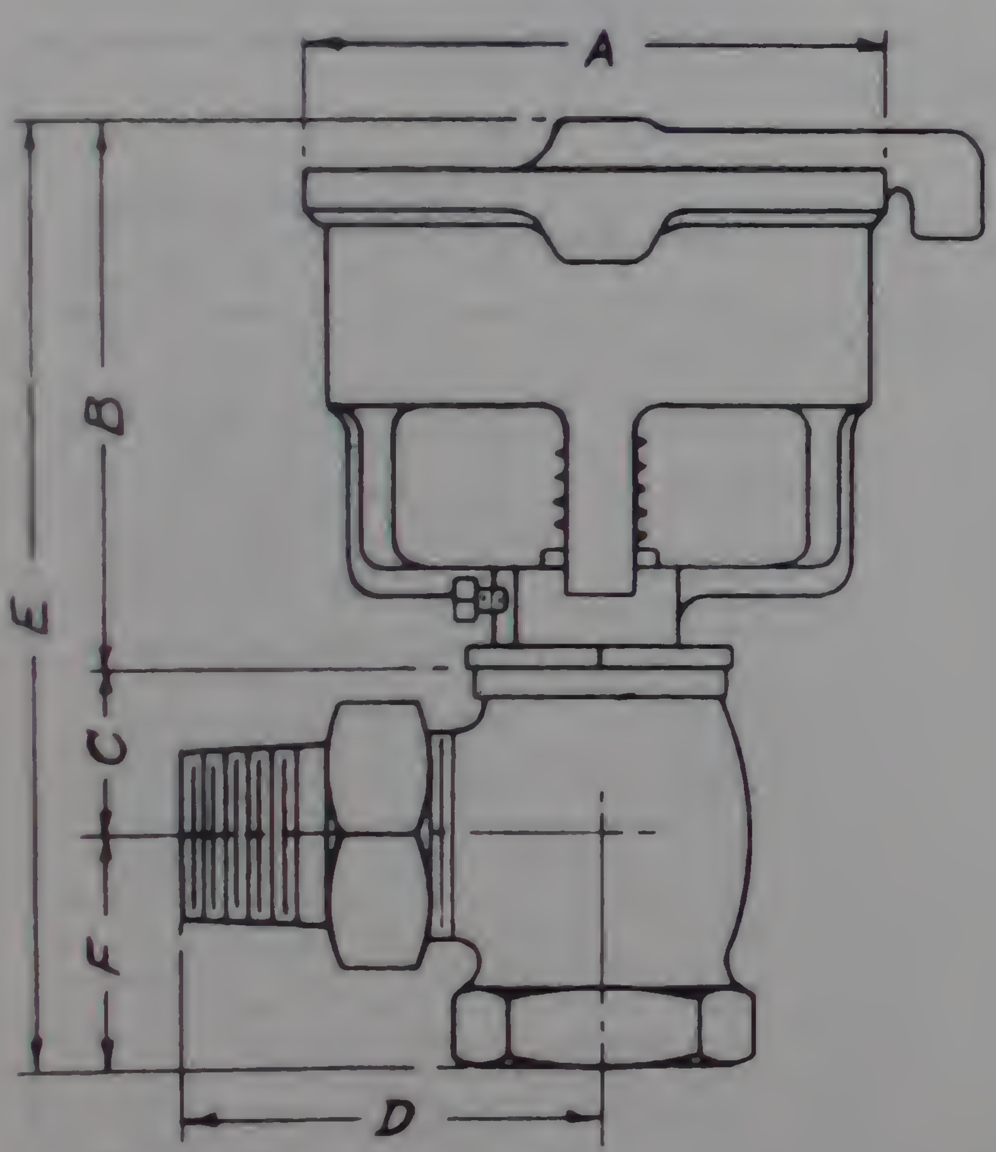


Figure 3

Angle Valve—3″ Top

Valve Size	½″	¾″	1″
A	3 7/8	3 7/8	3 7/8
B	4 11/32	4 7/32	4 1/4
C	27/32	27/32	1
D	2 13/16	2 7/8	3 1/8
E	6 5/16	6 3/8	6 3/4
F	1 1/8	1 5/16	1 1/2

Globe Valve—3″ Top

Valve Size	½″	¾″	1″
A	3 7/8	3 7/8	3 7/8
B	4 11/32	4 7/32	4 1/4
C	1 7/32	1 1/4	1 9/16
D	2 13/16	2 15/16	3 3/16
E	5 9/16	5 13/32	5 13/16
G	1 5/16	1 5/8	1 3/4

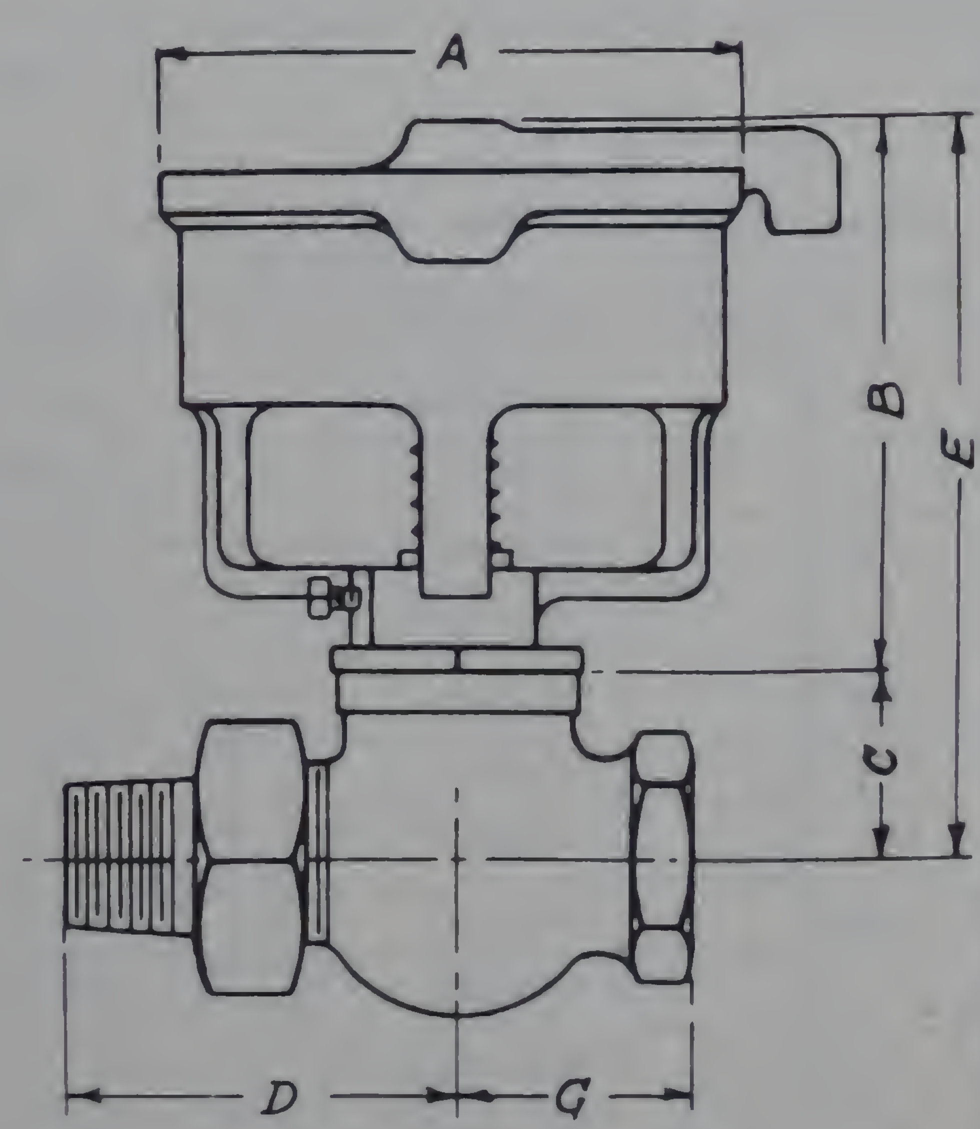


Figure 4

M-H ENGINEERING DATA

ELECTRIC MOTORIZED VALVES

Types K200, K201C, K203

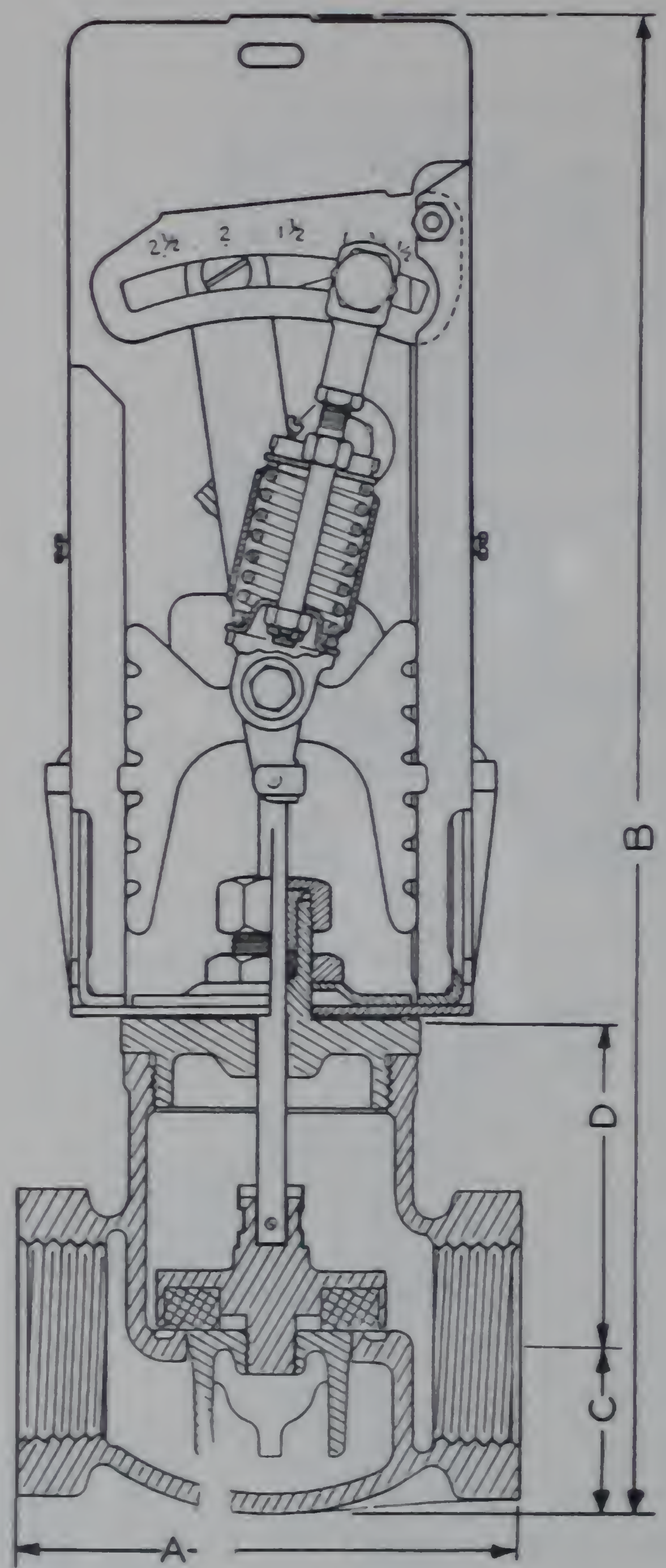


Fig. 1—Dimensional drawing of screwed Type K200B Motorized Valve.

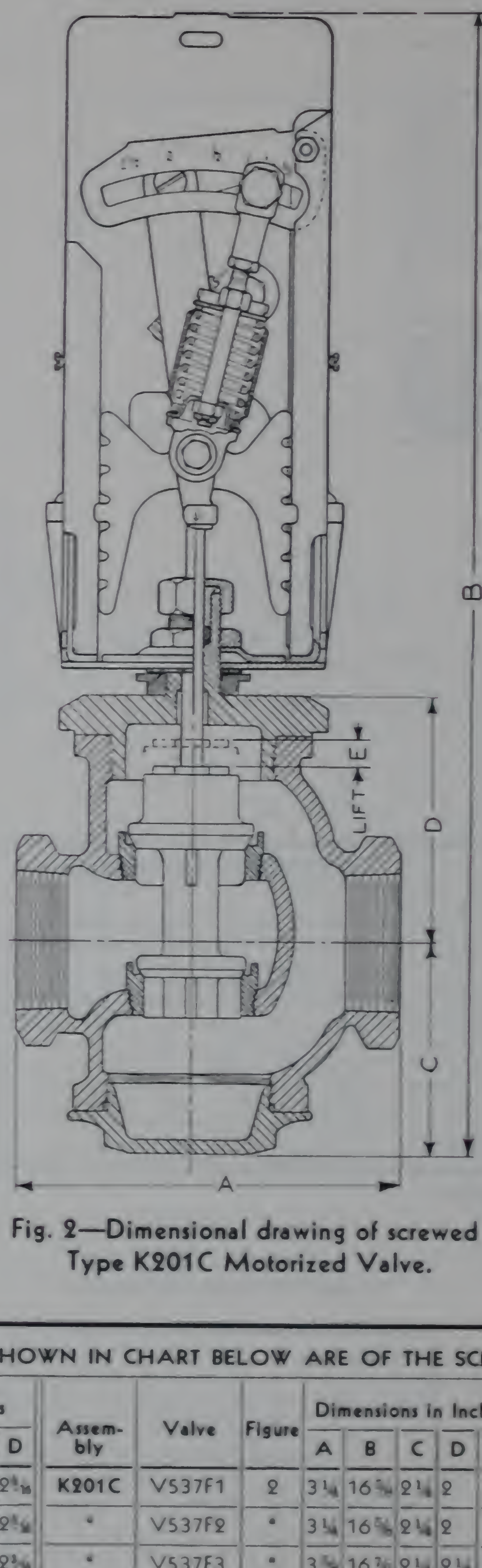


Fig. 2—Dimensional drawing of screwed Type K201C Motorized Valve.

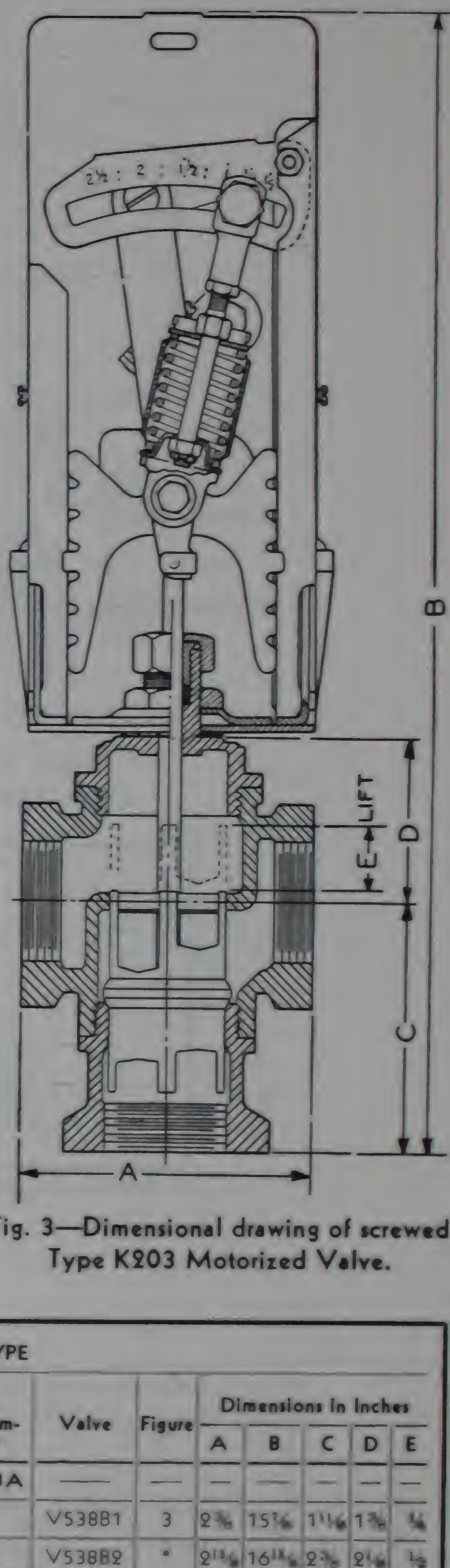


Fig. 3—Dimensional drawing of screwed Type K203 Motorized Valve.

ALL VALVES SHOWN IN CHART BELOW ARE OF THE SCREWED TYPE

Size	Assembly	Valve	Body Material	Figure	Dimensions A	B	C	D	Assembly	Valve	Figure	Dimensions in Inches A	B	C	D	E	Assembly	Valve	Figure	Dimensions in Inches A	B	C	D	E
1/4"	K200B	V575A30	Bronze	1	2 7/16	15 11/16	7/8	2 5/16	K201C	V537F1	2	3 1/4	16 3/4	2 1/4	2	3/8	K203A	—	—	—	—	—	—	—
3/8"	"	V575A31	"	"	2 7/16	15 11/16	7/8	2 5/16	"	V537F2	"	3 1/4	16 5/8	2 1/4	2	3/8	"	V538B1	3	2 3/8	15 7/16	1 11/16	1 3/8	1/4
1/2"	"	V575A1	"	"	2 5/8	15 3/4	1 1/4	2 3/16	"	V537F3	"	3 5/8	16 7/8	2 1/4	2 1/4	3/8	"	V538B2	"	2 13/16	16 13/16	2 3/8	2 1/16	1/2
3/4"	"	V575A2	"	"	3 3/16	15 3/4	1 1/4	2 3/16	"	V537F4	"	4 3/8	17 3/8	2 3/4	2 3/8	3/8	"	V538B3	"	3 1/4	17 5/8	2 11/16	2 1/16	5/8
1"	"	V575A3	"	"	3 7/16	15 7/8	1 1/4	2 5/16	"	V537F5	"	4 7/8	17 7/8	2 3/4	2 3/4	3/8	"	V538B4	"	3 11/16	17 7/8	3 1/4	2 1/4	13/16
1 1/4"	"	V575A4	"	"	3 7/8	16 3/16	1 3/8	2 7/16	"	V537F6	"	5 1/2	18 1/4	3	2 7/8	1/2	"	V538B5	"	4 5/16	18 7/16	3 1/2	2 7/16	1
1 1/2"	"	V575A5	"	"	4 1/2	16 5/16	1 5/16	2 7/16	—	—	—	—	—	—	—	—	"	V538B6	"	4 7/8	19 7/8	4 1/4	3 1/4	1 1/8
2"	"	V575A6	"	"	5 3/16	16 1/2	1 3/16	2 3/4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2 1/2"	"	V575A7	"	"	6 3/4	18 5/8	2 5/16	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3"	"	V575A8	"	"	7 7/8	19 9/16	2 3/4	4 1/2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2 1/2"	"	V575A24	"	"	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3"	"	V575A25	"	"	8 1/4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

M-H ENGINEERING DATA

ELECTRIC MOTORIZED VALVES

Type K910A Three-Way Mixing Valve

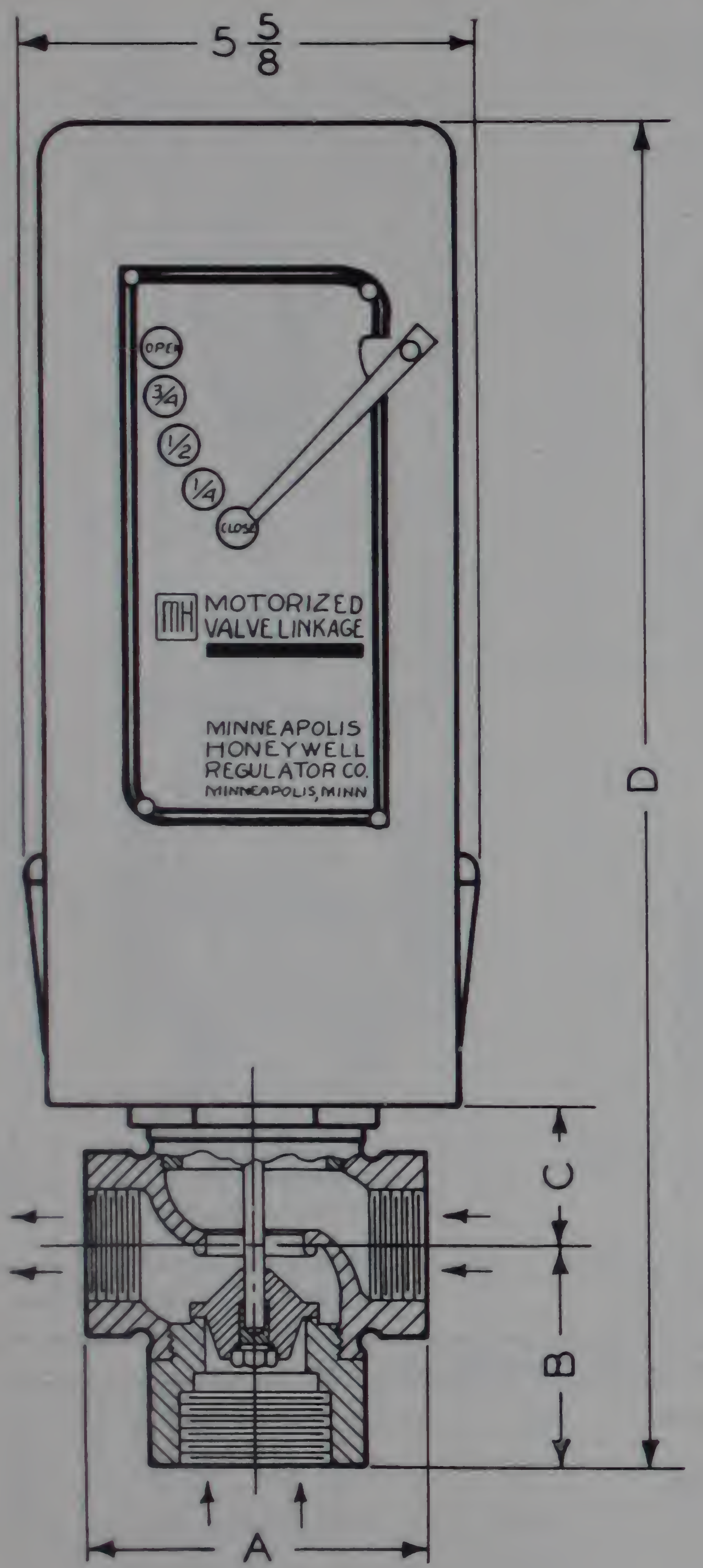


Figure 1

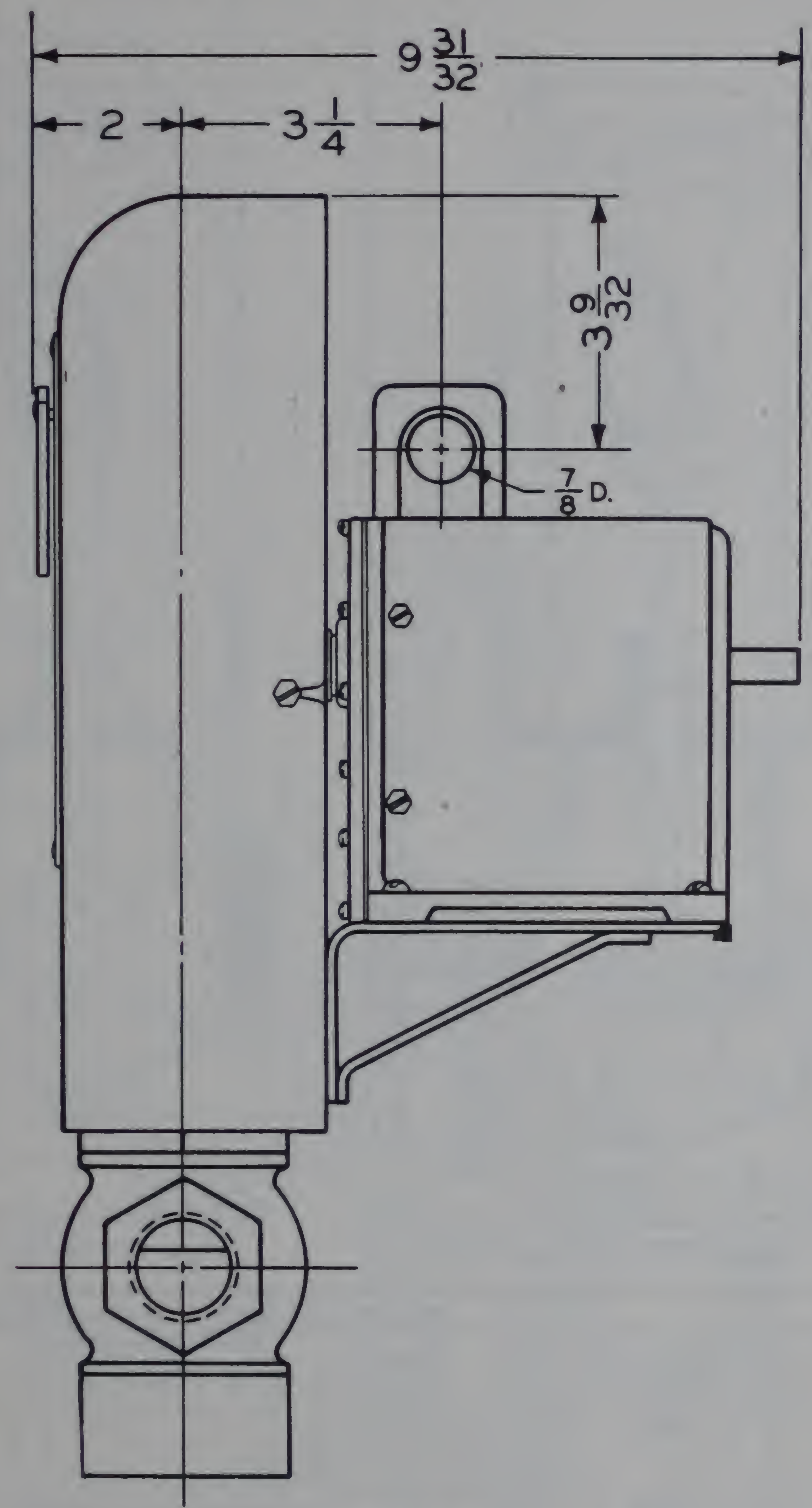


Figure 2

K910A Three-Way Mixing Valve (See Fig. 1)

Size	Assembly	Valve	Pattern	Material	Dimensions in Inches			
					A	B	C	D
1/2"	K910A	V581A1	Screwed	Bronze	3 1/8	1 27/32	1 25/64	15 31/64
3/4"	"	V581A2	"	"	3 3/8	2 7/32	1 25/64	15 55/64
1"	"	V581A3	"	"	3 7/8	2 21/64	1 19/32	16 11/64
1 1/4"	"	V581A4	"	"	4 1/4	2 23/32	1 25/32	16 3/4
1 1/2"	"	V581A5	"	"	4 3/4	2 15/16	2 1/16	17
2"	"	V581A6	"	"	5 7/8	3 3/8	2 5/16	17 15/16

M-H ENGINEERING DATA
ELECTRIC MOTORIZED VALVES
Types K900, K901, K903

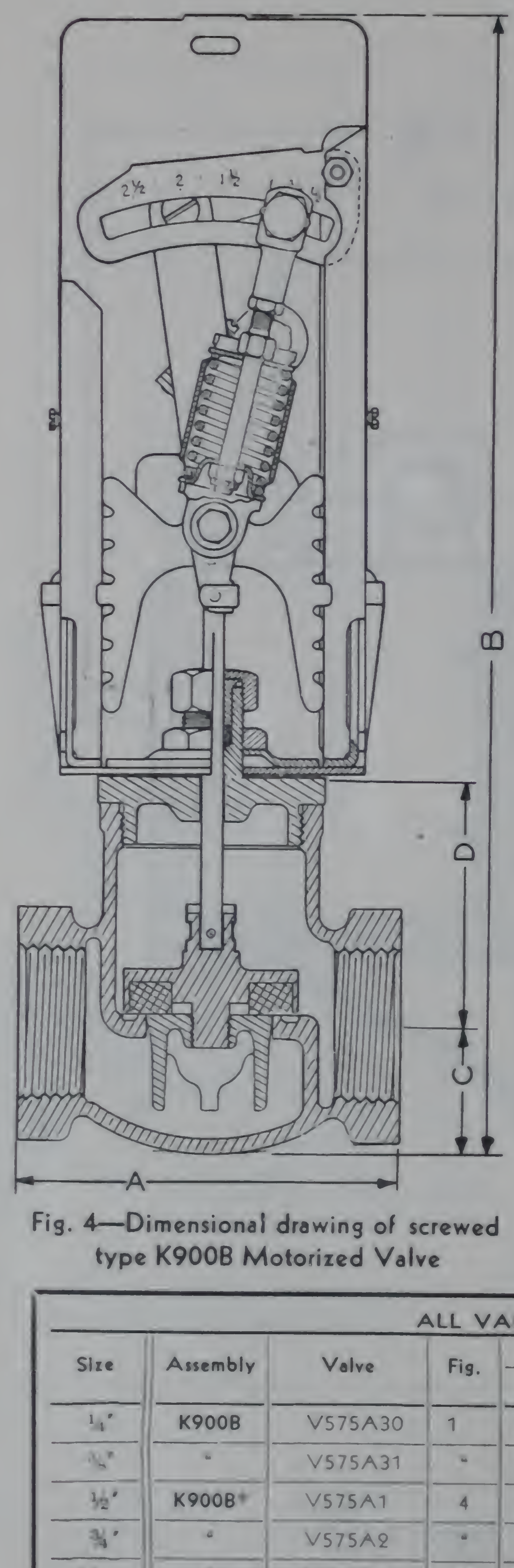


Fig. 4—Dimensional drawing of screwed type K900B Motorized Valve

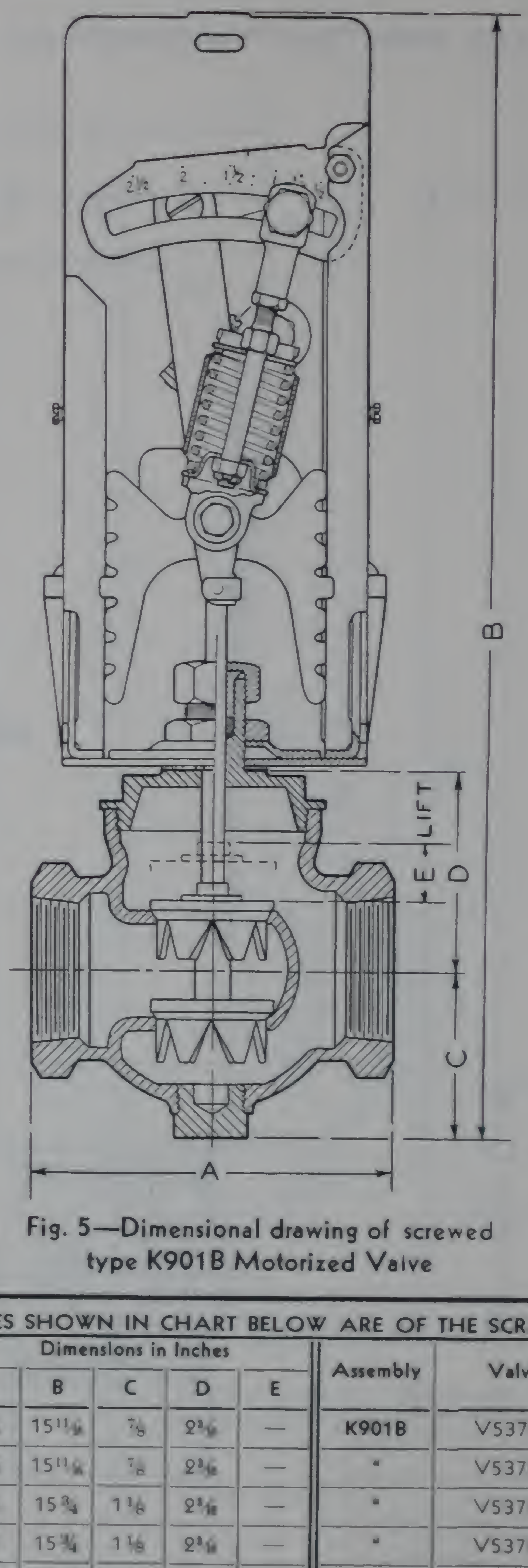


Fig. 5—Dimensional drawing of screwed type K901B Motorized Valve

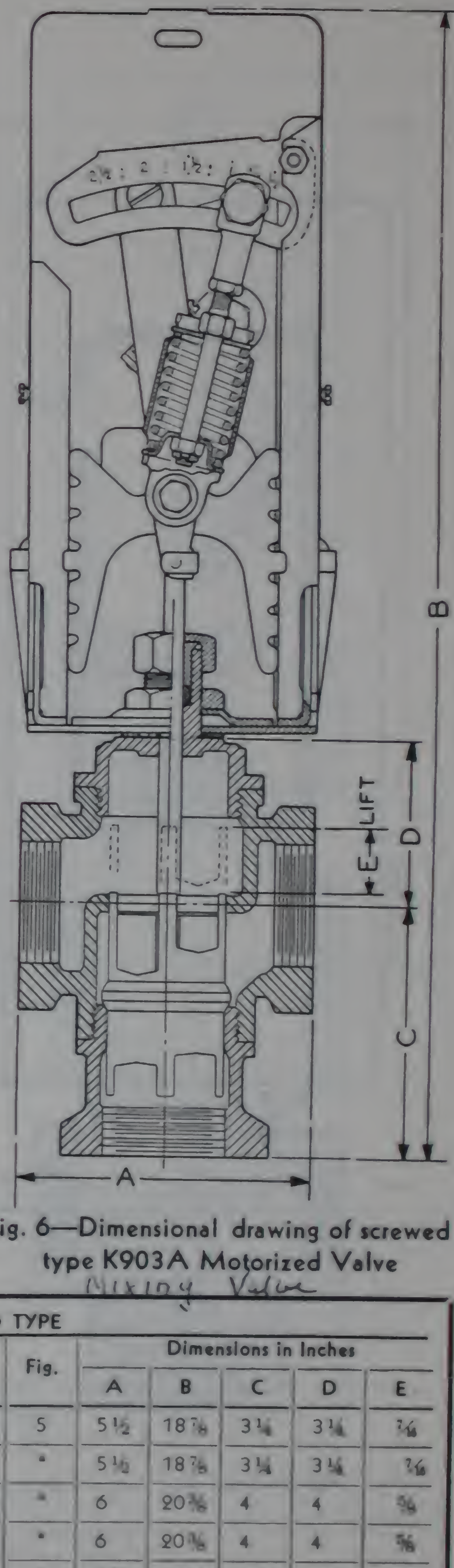


Fig. 6—Dimensional drawing of screwed type K903A Motorized Valve
Mixing Valve

ALL VALVES SHOWN IN CHART BELOW ARE OF THE SCREWED TYPE

Size	Assembly	Valve	Fig.	Dimensions in Inches					Assembly	Valve	Fig.	Dimensions in Inches				
				A	B	C	D	E				A	B	C	D	E
1/4"	K900B	V575A30	1	2 7/16	15 11/16	7/8	2 3/16	—	K901B	V537B1	5	5 1/2	18 7/8	3 1/4	3 1/4	7/16
3/8"	"	V575A31	"	2 7/16	15 11/16	7/8	2 3/16	—	"	V537B2	"	5 1/2	18 7/8	3 1/4	3 1/4	7/16
1/2"	K900B*	V575A1	4	2 5/8	15 3/4	1 1/8	2 3/16	—	"	V537B3	"	6	20 3/8	4	4	5/8
3/4"	"	V575A2	"	3 3/16	15 3/4	1 1/8	2 3/16	—	"	V537B4	"	6	20 3/8	4	4	5/8
1"	"	V575A3	"	3 7/16	15 7/8	1 1/4	2 3/16	—	"	V537B5	"	7 3/4	22 1/2	4 13/16	5 5/16	3/4
1 1/4"	"	V575A4	"	3 7/8	16 3/16	1 3/8	2 7/16	—	"	V537B6	"	9 1/8	23 5/8	5 3/8	5 7/8	1 1/4
1 1/2"	"	V575A5	"	4 1/2	16 1/16	1 9/16	2 7/16	—	"	V537B7	"	9	24 13/16	6	6 1/16	1 1/2
2"	"	V575A6	"	5 3/16	16 1/2	1 13/16	2 5/8	—	"	V537B8	"	11 3/16	26 3/16	6 3/4	7 1/16	1 1/2
2 1/2"	"	V575A7	"	6 3/4	18 5/8	2 3/16	4	—	—	—	—	—	—	—	—	—
3"	"	V575A8	"	7 7/8	19 5/16	2 5/8	4 1/2	—	—	—	—	—	—	—	—	—
1/2"	K903A	V538B1	6	2 3/8	15 7/16	1 11/16	1 3/8	1/4	—	—	—	—	—	—	—	—
3/4"	"	V538B2	"	2 13/16	16 13/16	2 3/8	2 1/16	1/2	—	—	—	—	—	—	—	—
1"	"	V538B3	"	3 1/4	17 5/8	2 11/16	2 5/16	5/8	—	—	—	—	—	—	—	—
1 1/4"	"	V538B4	"	3 11/16	17 7/8	3 1/4	2 1/4	13/16	—	—	—	—	—	—	—	—
1 1/2"	"	V538B5	"	4 3/16	18 7/16	3 1/2	2 7/16	1	—	—	—	—	—	—	—	—
2"	"	V538B6	"	4 7/8	19 3/4	4 1/4	3 1/4	1 3/16	—	—	—	—	—	—	—	—

*K900B body materials same as K200B. See table, page 28. Also available in 1/4" and 3/8" sizes. See K200B for dimensions.

M-H ENGINEERING DATA

ELECTRIC MOTORIZED VALVES

Types K202A, B, and C

Size	Assembly	Valve	Pattern	Figure	Dimensions in Inches				
					A	B	C	D	E
$\frac{1}{2}$"	K202A	V58A1	Screwed	2	3	$15\frac{15}{16}$	$1\frac{1}{8}$	$2\frac{7}{16}$	$\frac{5}{16}$
$\frac{3}{4}$"	"	V58A2	"	"	3	$15\frac{15}{16}$	$1\frac{1}{8}$	$2\frac{7}{16}$	$\frac{5}{16}$
1"	"	V58A3	"	"	$3\frac{5}{8}$	$16\frac{13}{16}$	$1\frac{3}{8}$	$3\frac{1}{16}$	$\frac{7}{16}$
$1\frac{1}{4}$"	"	V58A4	"	"	$4\frac{1}{4}$	$17\frac{7}{16}$	$1\frac{9}{16}$	$3\frac{1}{2}$	$\frac{1}{2}$
$1\frac{1}{2}$"	"	V58A5	"	"	$4\frac{5}{8}$	$17\frac{15}{16}$	$1\frac{15}{16}$	$3\frac{5}{8}$	$\frac{9}{16}$
2"	"	V58A6	"	"	$5\frac{9}{16}$	$18\frac{13}{16}$	$2\frac{1}{4}$	$4\frac{3}{16}$	$\frac{5}{8}$
$2\frac{1}{2}$"	K202B	V58B1	"	"	$6\frac{5}{8}$	$19\frac{13}{16}$	$2\frac{3}{4}$	$4\frac{11}{16}$	$\frac{3}{4}$
3"	"	V58B2	"	"	$8\frac{1}{2}$	$20\frac{7}{16}$	$3\frac{3}{8}$	$4\frac{11}{16}$	$\frac{13}{16}$
$3\frac{1}{2}$"	K202C	V58C1	Flanged	3	11	$24\frac{11}{16}$	5	$7\frac{5}{16}$	1
4"	"	V58C2	"	"	12	$24\frac{15}{16}$	$5\frac{3}{4}$	$6\frac{13}{16}$	$1\frac{3}{16}$
5"	"	V58C3	"	"	13	$26\frac{1}{16}$	6	$7\frac{11}{16}$	$1\frac{7}{16}$
6"	"	V58C4	"	"	16	$32\frac{13}{16}$	8	$12\frac{7}{16}$	$1\frac{13}{16}$

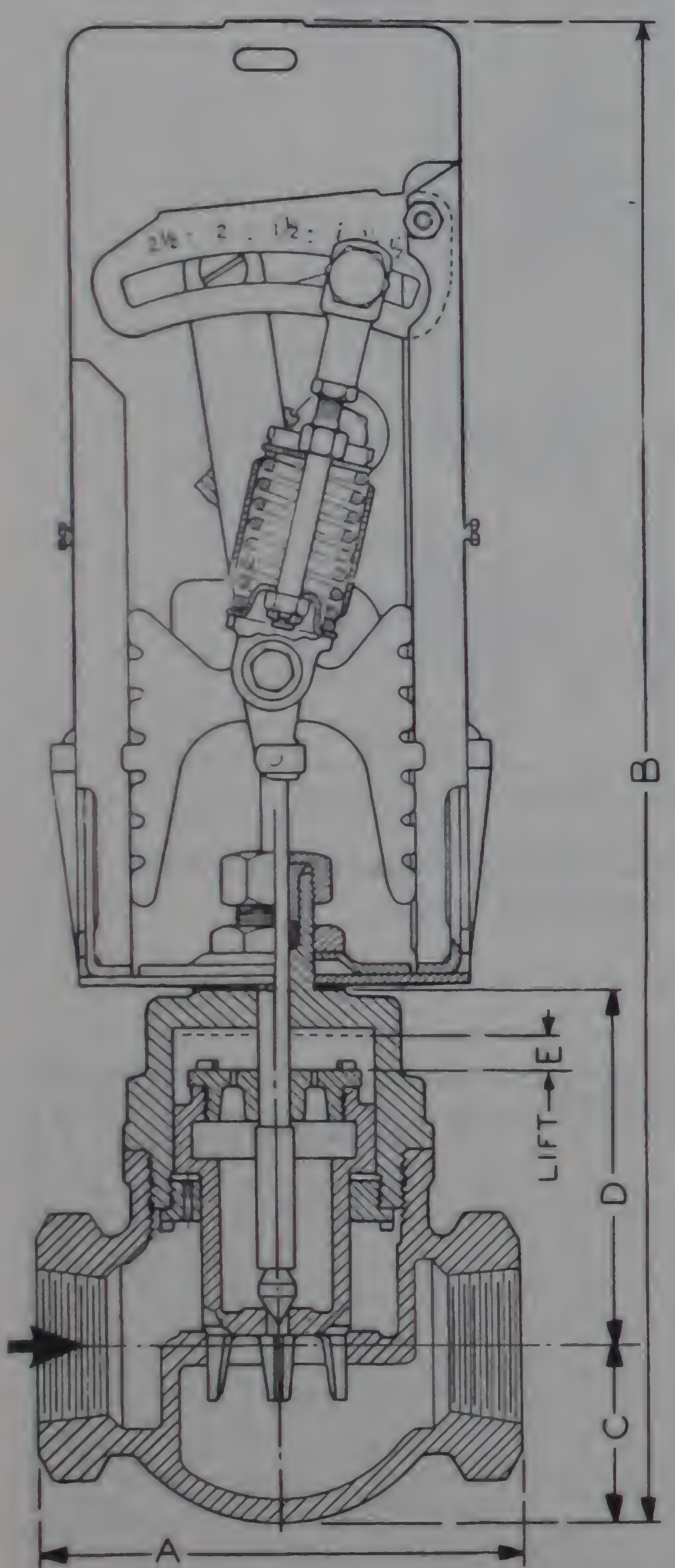


Fig. 2—Dimensional drawing of Type K202A Motorized Valve with V58A valve body.

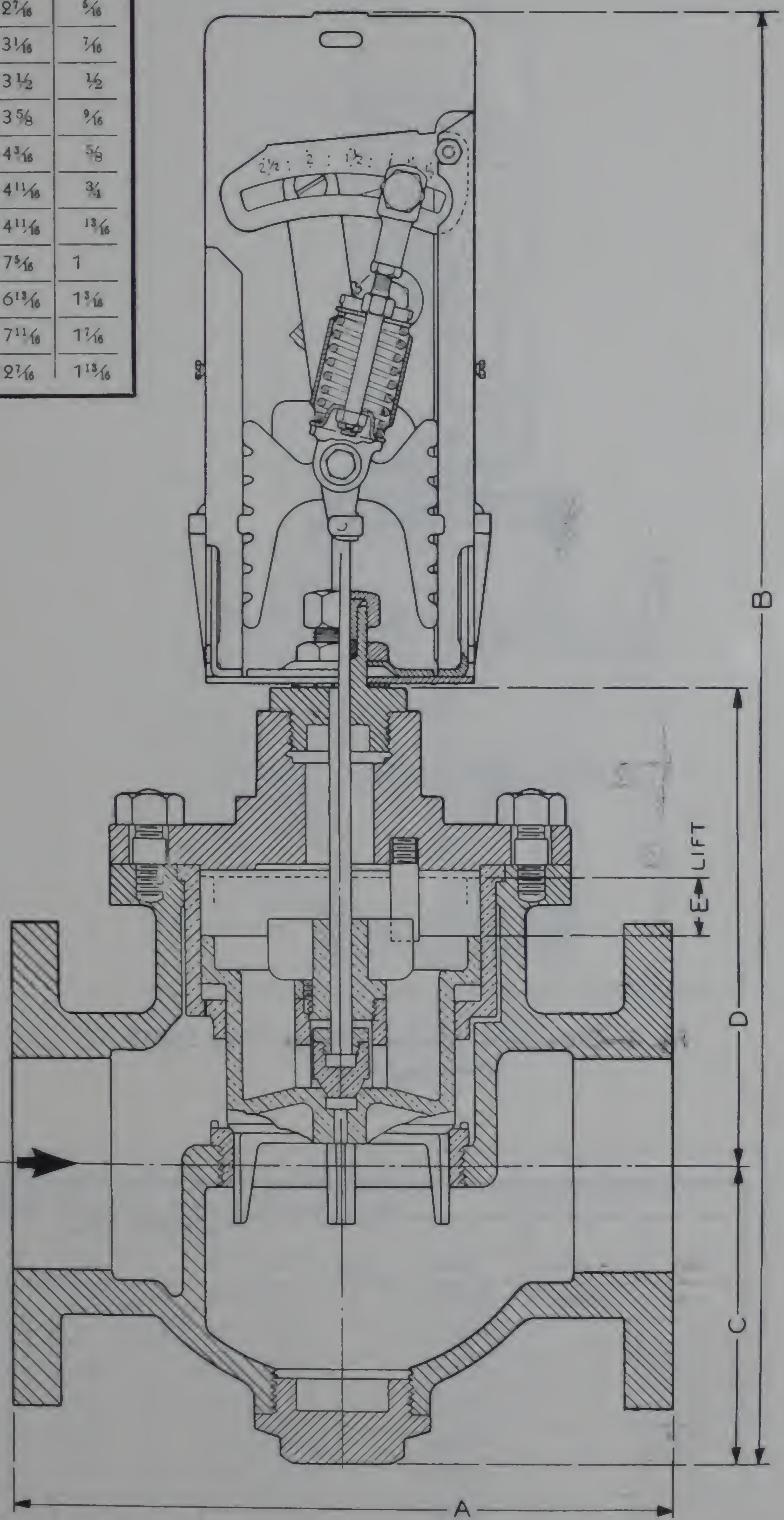


Fig. 3—Dimensional drawing of Type K202C Motorized Valve with V58C valve body.

M-H ENGINEERING DATA

ELECTRIC MOTORIZED VALVES

Types K201B, K203 (Flanged)

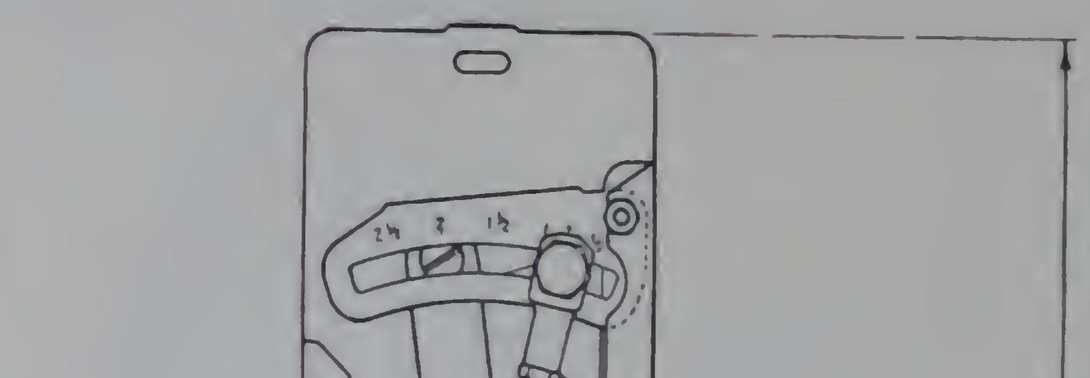


Fig. 4—Dimensional drawing of flanged Type K201B Motorized Valve.

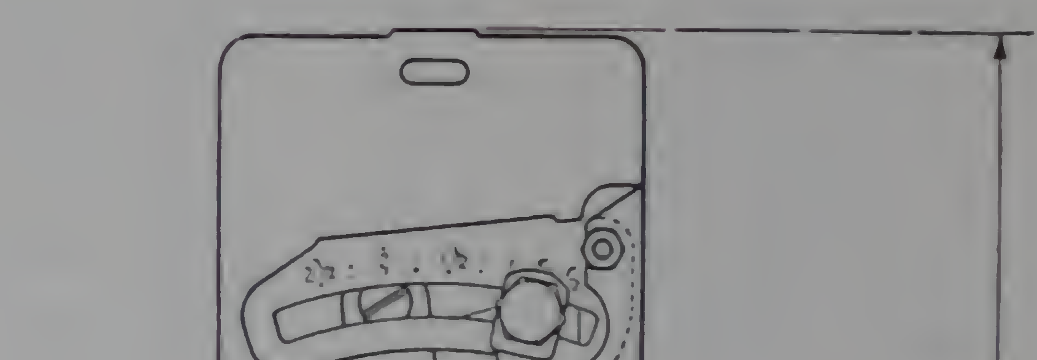


Fig. 5—Dimensional drawing of flanged Type K203 Motorized Valve.

Mixing Valve

ALL VALVES SHOWN IN CHART BELOW ARE OF THE FLANGED TYPE

Size	Assembly	Valve	Fig.	Dimensions in Inches A	B	C	D	E	Assembly	Valve	Fig.	Dimensions in Inches A	B	C	D	E
1 1/2"	K201B	V5378B28	4	8 1/8	22 1/2	4 13/16	5 5/16	3/4	———	———	—	—	—	—	—	—
2"	"	V5378B29	"	9 1/4	23 5/8	5 3/8	5 7/8	1 1/4	———	———	—	—	—	—	—	—
2 1/2"	"	V5378B30	"	10 1/2	24 13/16	6	6 7/16	1 1/2	K203A	V538B7	5	9	21 7/16	5 3/16	4 1/8	1 3/16
3"	"	V5378B31	"	11 3/4	26 5/16	6 3/4	7 1/16	1 1/2	"	V538B8	"	10	23 5/16	6 3/16	4 9/16	1 7/8
3 1/2"	"	V537B9	"	12 3/4	26 3/4	7 1/4	7 1/8	1 1/2	"	V538B9	"	11	24 3/4	7	5 3/16	1 7/8
4"	"	V537B10	"	14 9/16	29 11/16	8 9/16	8 3/4	1 1/2	"	V538B10	"	12	26 9/16	8 1/16	5 3/4	1 7/8
5"	"	V537B11	"	15 7/8	30 11/16	9 1/16	9 1/4	2	———	———	—	—	—	—	—	—
6"	"	V537B12	"	17 5/8	30 13/16	9	9 7/16	2	———	———	—	—	—	—	—	—

M-H ENGINEERING DATA

ELECTRIC MOTORIZED VALVES

Types K901 and K903 (Flanged)

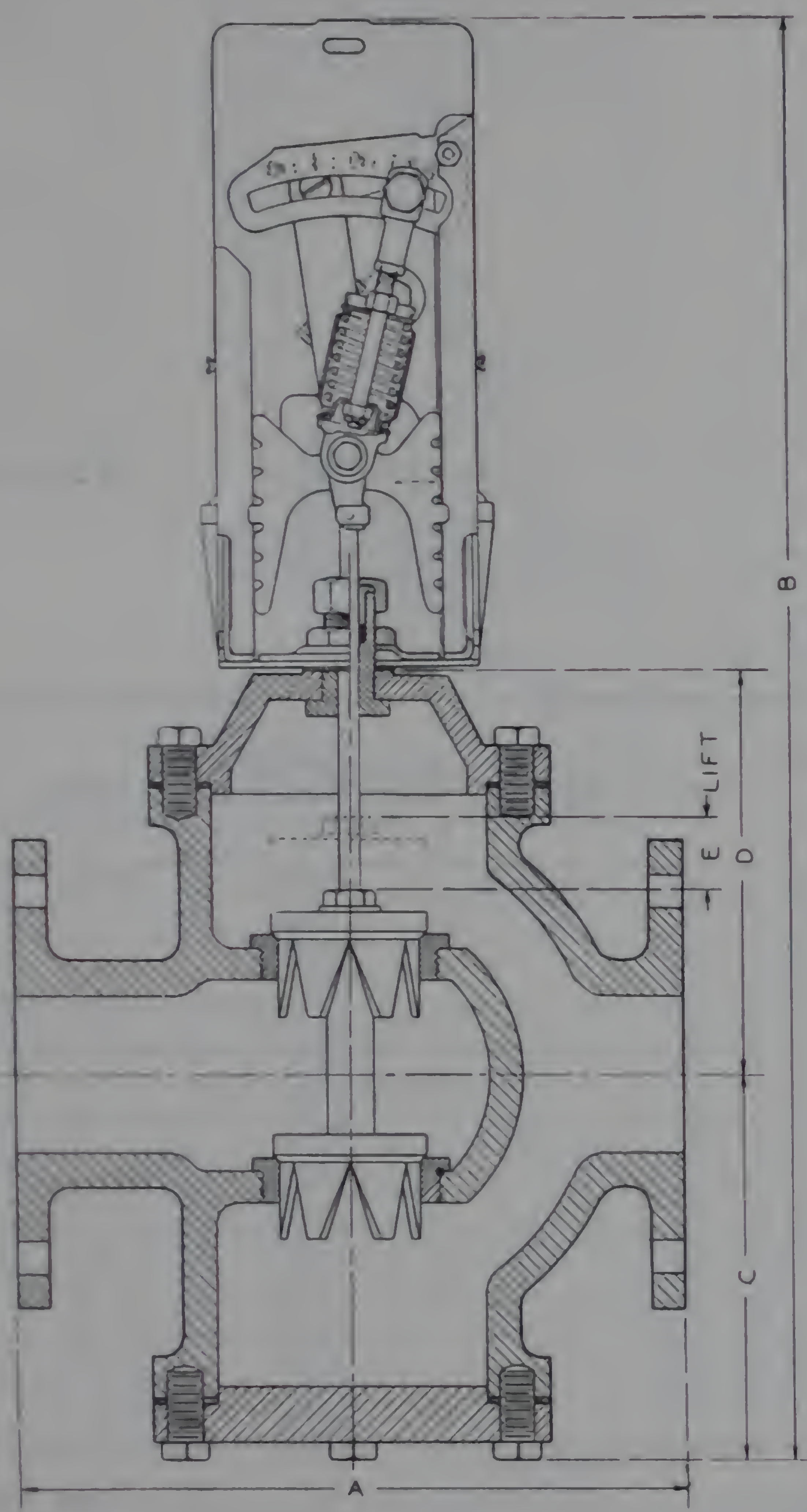


Fig. 2—Dimensional drawing of flanged type K901B Motorized Valve

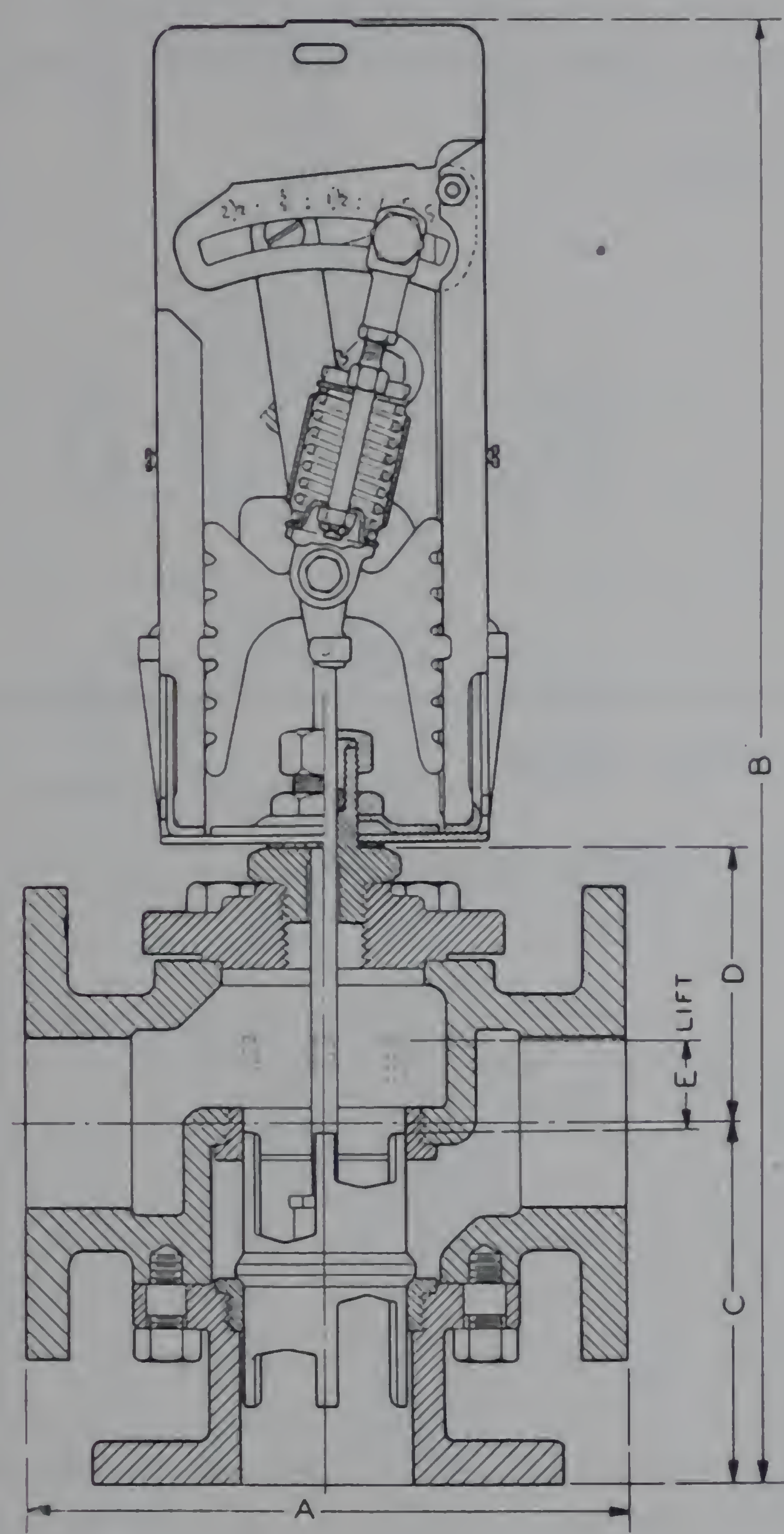


Fig. 3—Dimensional drawing of flanged type K903A Motorized Valve

Mixing Valve

ALL VALVES SHOWN IN CHART BELOW ARE OF THE FLANGED TYPE

Size	Assembly	Valve	Fig.	Dimensions in Inches A	B	C	D	E	Assembly	Valve	Fig.	Dimensions in Inches A	B	C	D	E
1 1/2"	K901B	V537B28	2	8 1/8	22 1/2	4 13/16	5 5/16	3/4	—	—	—	—	—	—	—	—
2"	"	V537B29	"	9 1/4	23 5/8	5 3/8	5 7/8	1 1/4	—	—	—	—	—	—	—	—
2 1/2"	"	V537B30	"	10 1/2	24 13/16	6	6 7/16	1 1/2	K903A	V538B7	3	9	21 7/8	5 3/8	4 1/8	1 3/8
3"	"	V537B31	"	11 3/4	26 3/16	6 3/4	7 1/16	1 1/2	"	V538B8	"	10	23 5/16	6 3/8	4 9/16	1 7/8
3 1/2"	"	V537B9	"	12 3/4	26 3/4	7 1/4	7 1/8	1 1/2	"	V538B9	"	11	24 3/4	7	5 3/8	1 7/8
4"	"	V537B10	"	14 9/16	29 11/16	8 9/16	8 3/4	1 1/2	"	V538B10	"	12	26 9/16	8 7/16	5 3/4	1 7/8
5"	"	V537B11	"	15 7/8	30 11/16	9 1/16	9 1/4	2	—	—	—	—	—	—	—	—
6"	"	V537B12	"	17 5/8	30 13/16	9	9 7/16	2	—	—	—	—	—	—	—	—

M-H ENGINEERING DATA

Roughing in dimensions of motorized valve assemblies using V537D and V537E Belfield double seated globe valve bodies.

Screwed Type

Flanged Type

VALVE ASSEMBLY Motor	Linkage	Valve Body O. S. Number	SIZE	PATTERN	DIMENSIONS IN INCHES A	B	C	LIFT	SERVICE INTENDED	MAX. PRESSURE With 60 Sec. or Slower Motor	BODY MATERIAL	TRIM
M204A	Q601A	V537D1	1/2"	Screwed	2 1/4	15 9/32	13 25/32	1/4"	2-Position	150#	Bronze	Bronze
"	"	V537D2	3/4"	"	2 3/4	16 1/32	14 5/32	5/16"	"	150#	"	"
"	"	V537D3	1"	"	3 3/8	16 21/32	14 15/32	3/8"	"	150#	"	"
"	"	V537D4	1 1/4"	"	4	17 1/8	14 5/8	7/16"	"	150#	"	"
"	"	V537D5	1 1/2"	"	4 1/2	17 5/8	14 7/8	1/2"	"	150#	"	"
"	"	V537D6	2"	"	5 3/8	18 9/16	15 3/16	5/8"	"	150#	"	"
"	"	V537D7	2 1/2"	"	6 3/8	19 7/16	15 11/16	3/4"	"	150#	"	"
"	"	V537D8	3"	"	7 1/8	21	16 1/4	7/8"	"	150#	"	"
"	"	V537D9	1/2"	"	2 1/2	15 11/16	13 5/16	1/4"	"	150#	Semi-steel	"
"	"	V537D10	3/4"	"	3 1/8	16 3/16	14 3/16	5/16"	"	150#	"	"
"	"	V537D11	1"	"	4 5/16	17 1/2	14 7/8	3/8"	"	150#	"	"
"	"	V537D12	1 1/4"	"	4 5/8	17 7/8	15	7/16"	"	150#	"	"
"	"	V537D13	1 1/2"	"	5 5/8	18 5/8	15 1/8	1/2"	"	150#	"	"
"	"	V537D14	2"	"	6 3/4	20 1/16	16 9/16	5/8"	"	150#	"	"
"	"	V537D15	2 1/2"	"	7 7/8	20 7/8	16 7/8	3/4"	"	150#	"	"
"	"	V537D16	3"	"	8 3/4	22 1/2	18	7/8"	"	150#	"	"
M204A or M904E	Q601A	V537E1	1/2"	Screwed	3 3/8	16 29/32	14 23/32	1/2"	Modulating or 2-Position	150#	Bronze	Bronze
"	"	V537E2	3/4"	"	3 3/8	16 29/32	14 23/32	1/2"	"	150#	"	"
"	"	V537E3	1"	"	3 3/8	16 29/32	14 23/32	1/2"	"	150#	"	"
"	"	V537E4	1 1/4"	"	4	17 3/4	14 7/8	9/16"	"	150#	"	"
"	"	V537E5	1 1/2"	"	4 1/2	17 5/8	14 7/8	5/8"	"	150#	"	"
"	"	V537E6	2"	"	5 3/8	18 9/16	15 3/16	7/8"	"	150#	"	"
"	"	V537E7	2 1/2"	"	6 3/4	19 5/8	15 7/8	1"	"	150#	"	"
"	"	V537E8	3"	"	7 1/8	21	16 1/4	1 1/8"	"	150#	"	"
"	"	V537E9	2"	Flanged	7 1/4	20 1/16	16 9/16	7/8"	"	125#	Semi-steel	"
"	"	V537E10	2 1/2"	"	8 1/2	20 7/8	16 7/8	1"	"	125#	"	"
"	"	V537E11	3"	"	8 3/4	22 1/2	18	1 1/8"	"	125#	"	"
"	"	V537E13	4"	"	10 7/8	25	19	1 3/4"	"	125#	"	"
"	"	V537E14	5"	"	12 1/8	25 3/4	19 7/8	2 3/16"	"	100#	"	"
"	"	V537E15	6"	"	13 3/4	27 3/4	20 7/8	2 3/8"	"	* 80#	"	"
"	"	V537E16	1/2"	Screwed	4 5/16	17 1/2	14 7/8	1/2"	"	150#	"	"
"	"	V537E17	3/4"	"	4 5/16	17 1/2	14 7/8	1/2"	"	150#	"	"
"	"	V537E18	1"	"	4 5/16	17 1/2	14 7/8	1/2"	"	150#	"	"
"	"	V537E19	1 1/4"	"	4 5/8	17 7/8	15	9/16"	"	150#	"	"
"	"	V537E20	1 1/2"	"	5 5/8	18 5/8	15 1/2	5/8"	"	150#	"	"
"	"	V537E21	2"	"	6 3/4	20 1/16	16 9/16	7/8"	"	150#	"	"
"	"	V537E22	2 1/2"	"	7 7/8	20 7/8	16 7/8	1"	"	150#	"	"
"	"	V537E23	3"	"	8 3/4	22 1/2	18	1 1/8"	"	—	—	—

*Pressure rating based on 120 or 240 second timing.

M-H ENGINEERING DATA

PNEUMATIC COIL VALVES

Type V053

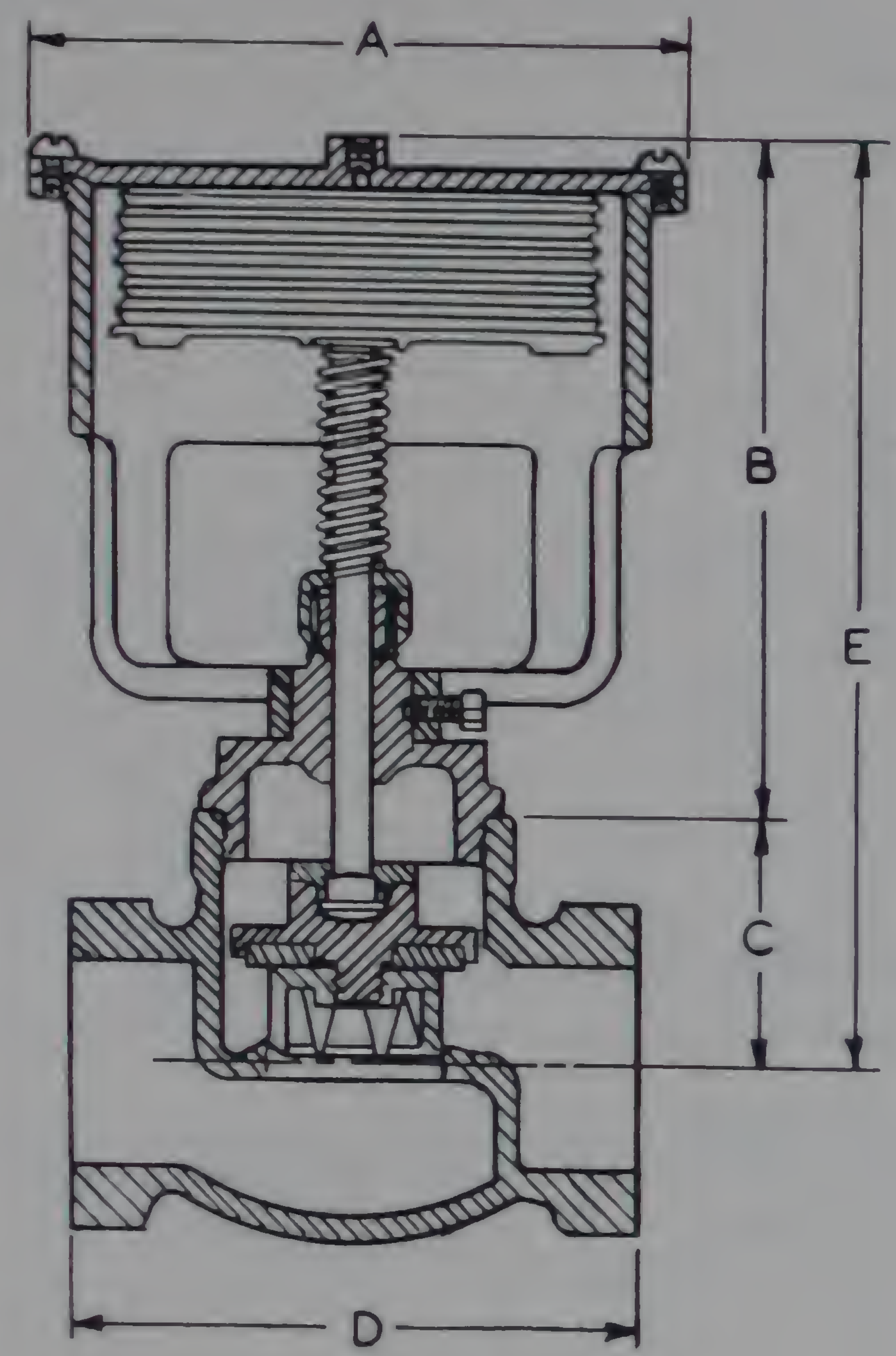


Fig. 1

Type V054

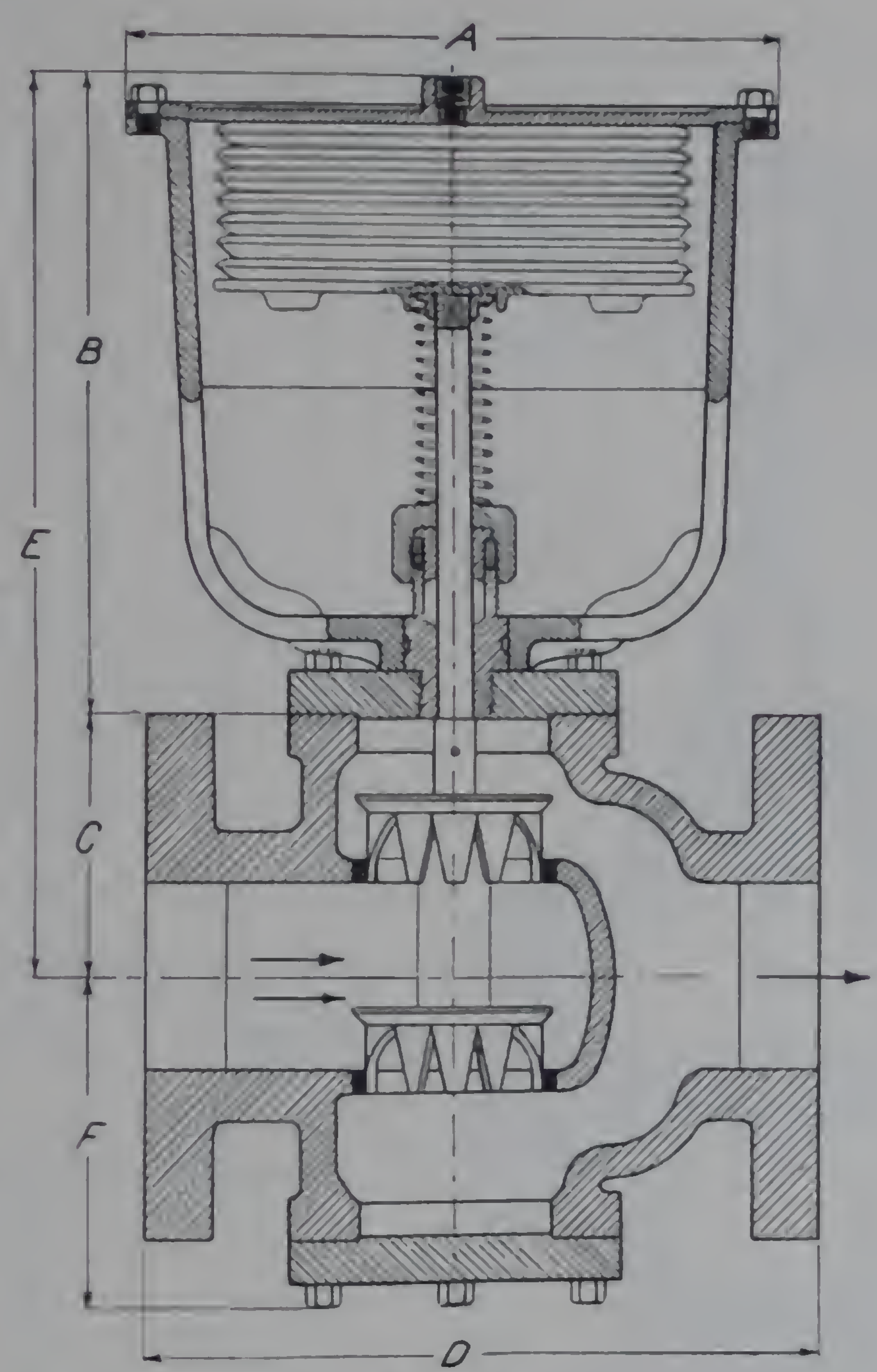


Fig. 2

SINGLE SEATED—V053A (Refer to Fig. 1)

Valve Size	SCREWED BRONZE BODY						
	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"
A	5 5/8	5 5/8	5 5/8	5 5/8	5 5/8	5 5/8	5 5/8
B	5 19/32	5 19/32	5 19/32	5 15/32	5 1/2	5 1/2	5 1/2
C	1 7/8	1 7/8	1 29/32	1 31/32	2 1/16	2 3/16	2 3/16
D	2 7/16	2 7/16	2 5/8	3 3/16	3 7/16	3 7/8	4 1/2
E	7 1/2	7 1/2	7 1/2	7 7/16	7 9/16	7 11/16	7 11/16

SINGLE SEATED—V053B (Refer to Fig. 1)

Valve Size	SCREWED BRONZE BODY							
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
A	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16
B	8 7/8	8 3/4	8 3/4	8 3/4	8 25/32	8 25/32	9 21/32	9 25/32
C	1 29/32	1 31/32	2 1/16	2 3/16	2 3/16	2 3/32	2 13/16	3 3/16
D	2 5/8	3 3/16	3 7/16	3 7/8	4 1/2	5 3/16	6 3/4	7 27/32
E	10 25/32	10 23/32	10 13/16	10 15/16	10 31/32	10 7/8	12 15/32	12 31/32

SINGLE SEATED NORMALLY OPEN TYPE—V053B & C (Refer to Fig. 1)

Valve Size	SCREWED IRON BODY			SCREWED BRONZE BODY			SCREWED IRON BODY			FLANGED IRON BODY		
	2"	2 1/2"	3"	2"	2 1/2"	3"	2"	2 1/2"	3"	4"	5"	6"
A	9 9/16	9 9/16	9 9/16	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16
B	9 7/16	9 1/8	9 1/8	11 17/32	12 13/32	12 17/32	12 3/16	11 7/8	11 7/8	11 13/16	11 7/8	11 7/8
C	2 5/8	3	3 1/2	2 3/32	2 13/16	3 3/16	2 5/8	3	3 1/2	4 3/8	5 1/8	5 7/8
D	6 1/2	8	8 1/4	5 3/16	6 3/4	7 27/32	6 1/2	8	8 1/4	12	14	16
E	12 1/16	12 1/8	12 5/8	13 5/8	15 7/32	15 23/32	14 13/16	14 7/8	15 3/8	16 3/16	17	17 3/4

V053-A, B, C—Normally Open Type.

DOUBLE SEATED COIL VALVES—Type V054 (Refer to Fig. 2)

Valve Size	SCREWED AND FLANGED ENDS										
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	5"	6"
A	5 5/8"	5 5/8"	5 5/8"	5 5/8"	5 5/8"	5 5/8"	9 9/16"	9 9/16"	12 9/16"	12 9/16"	12 9/16"
B	5 5/8"	5 11/16"	5 9/16"	5 11/16"	5 9/16"	9 1/2"	9 1/2"	9 1/2"	12 1/4"	12 1/4"	12 1/4"
C	1 1/8"	1 1/8"	1 7/16"	1 9/16"	1 3/4"	3 1/4"	3"	4 1/8"	4 1/2"	5 1/8"	6 1/8"
D	2 7/8"	2 7/8"	3 1/2"	4"	4 1/2"	7 1/4"	7 1/4"	9"	10 1/2"	11 1/4"	12 1/2"
E	6 3/4"	6 13/16"	7"	7 1/4"	7 5/16"	12 3/4"	12 1/2"	13 5/8"	16 3/4"	17 3/8"	18 3/8"
F	1 11/16"	1 9/16"	1 15/16"	2 1/8"	2 5/16"	2 1/2"	2 1/4"	5 1/4"	5 7/8"	7 1/4"	7 1/2"

M-H ENGINEERING DATA

PNEUMATIC COIL VALVES

Type V053E & F

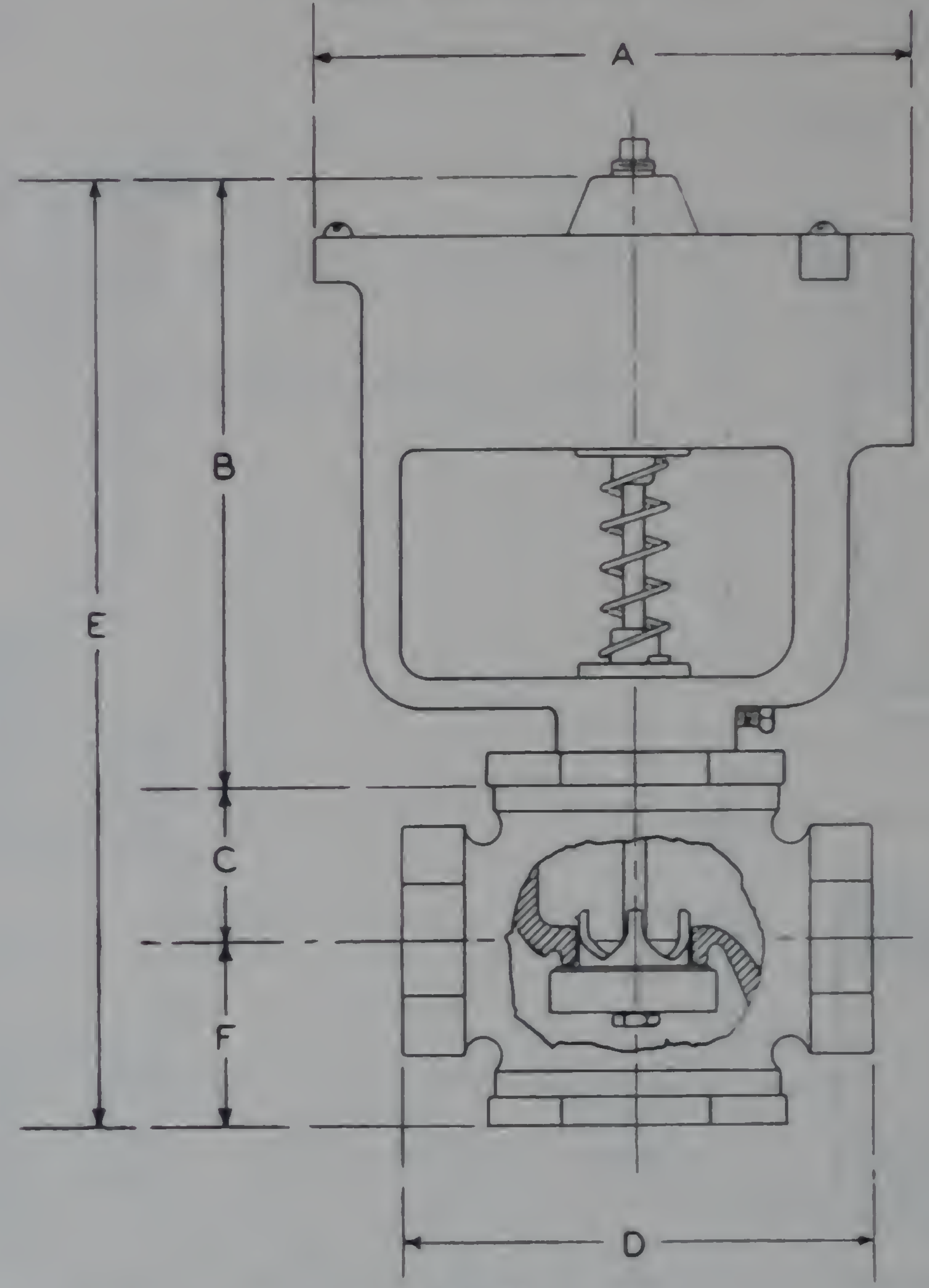


Fig. 3

NORMALLY CLOSED TYPE—V053E and F (Refer to Fig. 3)

Valve Size	SCREWED BRONZE BODY									
	V053E				V053F					
	½"	¾"	1"	1¼"	½"	¾"	1"	1¼"	1½"	2"
A	5⅝	5⅝	5⅝	5⅝	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16
B	5½	5½	5½	5½	8¾	8¾	8¾	8 25/32	8 25/32	8 25/32
C	1 5/32	1 5/32	1⅜	1 17/32	1 5/32	1 5/32	1⅜	1 17/32	1 13/16	2 1/32
D	3⅛	3⅜	3⅞	4¼	3⅛	3⅜	3⅞	4¼	4¾	5⅞
E	8⅛	8⅛	8 15/32	8 11/16	11⅜	11⅜	11 23/32	11 31/32	12½	13¼
F	1 15/32	1 15/32	1 19/32	1 21/32	1 15/32	1 15/32	1 19/32	1 21/32	1 29/32	2 7/16

K0900A (Refer to Fig. 4)

Size	Body	A	B
¼ & ⅜	V575B31 & B32	2 3/16	2 7/16
½	V575B1	2¼	2⅝
¾	V575B2	2 3/16	3 3/16
1	V575B3	2 5/16	3 7/16
1¼	V575B4	2 7/16	3⅞
1½	V575B5	2 7/16	4½
2	V575B6	2⅜	5 3/16
2½	V575B7	4	6¾
3	V575B8	4½	7 27/32

K0901A (Refer to Fig. 4 - Body like Fig. 2)

Size	Body	A	B
½	V578A1	2 3/16	3¼
¾	V578A2	2 5/16	3 9/16
1	V578A3	2 9/16	4 5/16
1¼	V578A4	2 7/16	4 7/16
1½	V578A5	3	5 7/16
2	V578A6	3 9/16	6 9/16
2½	V578A7	5 13/16	9
3	V578A8	6 7/16	11 3/16

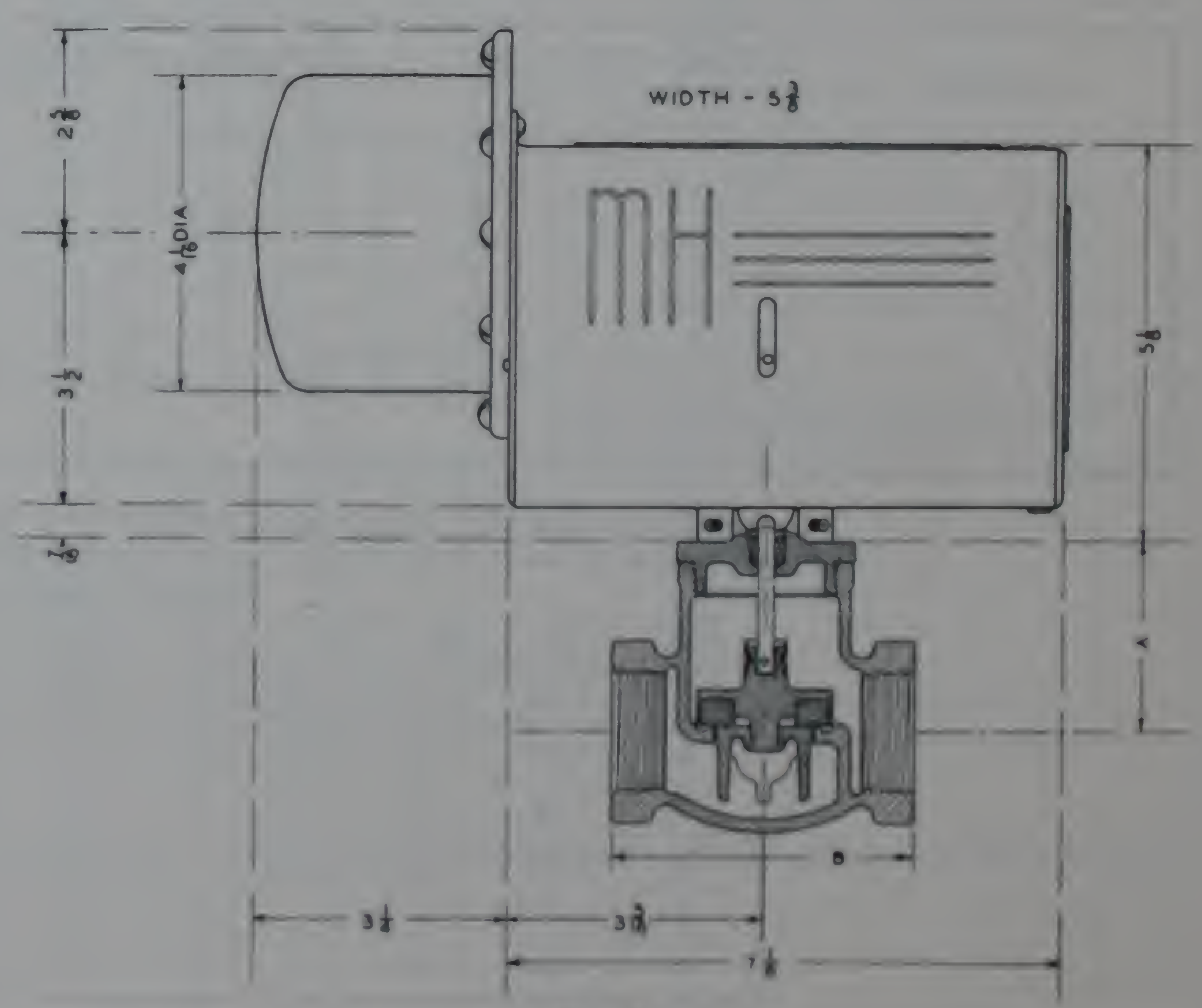


Fig. 4

M-H ENGINEERING DATA

PNEUMATIC COIL VALVES

THREE-WAY MIXING VALVE—Type V055A (Refer to Fig. 5)

Valve Size	SCREWED BRONZE BODY					
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
A	5 5/8	5 5/8	5 5/8	5 5/8	5 5/8	5 5/8
B	6 21/32	6 21/32	6 7/8	7 1/32	7 5/16	7 9/16
C	1 27/32	2 7/32	2 5/16	2 23/32	2 15/16	3 3/8
D	3 1/8	3 3/8	3 7/8	4 1/4	4 3/4	5 7/8

THREE-WAY MIXING VALVE—Type V055B (Refer to Fig. 5)

Valve Size	SCREWED BRONZE BODY						Screwed Iron Body	
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
A	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16	9 9/16
B	9 29/32	9 29/32	10 1/8	10 5/16	10 19/32	10 13/16	11 1/2	11 7/8
C	1 27/32	2 27/32	2 5/16	2 23/32	2 15/16	3 3/8	5 1/8	5 27/32
D	3 1/8	3 3/8	3 7/8	4 1/4	4 3/4	5 7/8	8	8 1/4

THREE-WAY MIXING VALVE—Type V055C (Refer to Fig. 5)

Valve Size	SCREWED IRON BODY		FLANGED IRON BODY		
	2 1/2"	3"	4"	5"	6"
A	12 9/16	12 9/16	12 9/16	12 9/16	12 9/16
B	14 1/4	14 5/8	15 3/8	16 5/16	17 3/16
C	5 1/8	5 27/32	7 7/16	8 9/16	9 11/16
D	8	8 1/4	12	14	15

Type V055

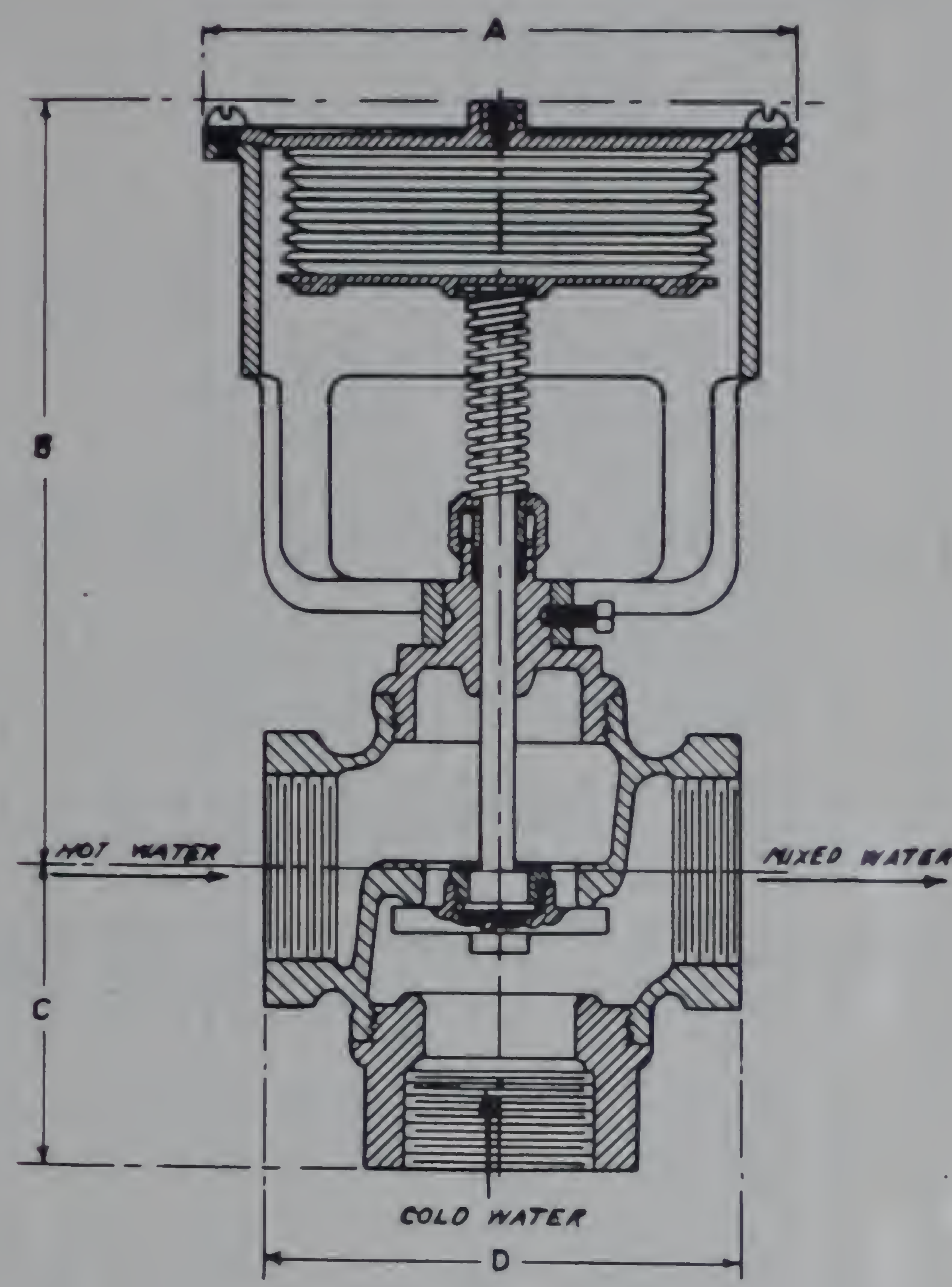


Fig. 5

THREE-WAY MIXING VALVE—Type K0903B (Refer to Fig. 6)

K0903B—PRESSURE RATING

VALVE SIZE Standard Tops	PRESSURE RATING Unbalanced Pressure
K0903B, 1/2" Screwed	60
3/4" "	60
1" "	50
1 1/4" "	33
1 1/2" "	22
2" "	12

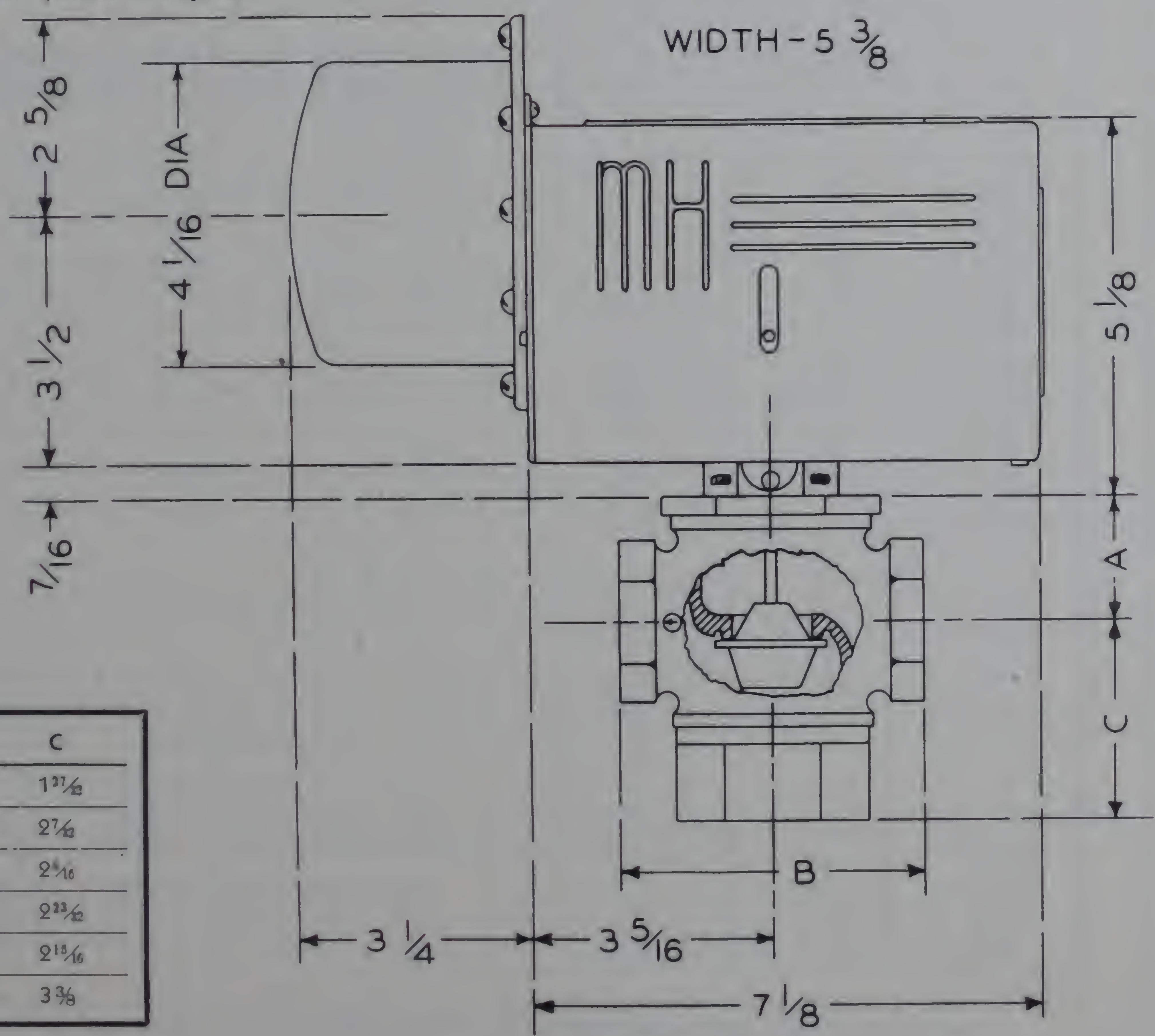


Fig. 6

K0903B—VALVE BODY DIMENSIONS

SIZE	BODY	A	B	C
1/2"	V581B1	1 13/32	3 1/8	1 27/32
3/4"	V581B2	1 13/32	3 3/8	2 7/32
1"	V581B3	1 19/32	3 7/8	2 5/16
1 1/4"	V581B4	1 25/32	4 1/4	2 23/32
1 1/2"	V581B5	2 1/16	4 3/4	2 15/16
2"	V581B6	2 5/16	5 7/8	3 3/8

Dimensions of Operator Shown in Fig. 6

M-H ENGINEERING DATA
RELATIVE HUMIDITY TABLE
Pressure = 30.0″

Air Temp. Dry Bulb Reading Degrees Fahrenheit	Difference Between Wet and Dry Bulb Thermometers in Degrees Fahrenheit																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
20	85	70	55	40	26	12																																		
21	85	71	56	42	28	15	1																																	
22	86	71	58	44	31	17	4																																	
23	86	72	59	46	33	20	7																																	
24	87	73	60	47	35	22	10																																	
25	87	74	62	49	37	25	13	1																																
26	87	75	63	51	39	27	16	4																																
27	88	76	64	52	41	29	18	7																																
28	88	76	65	54	43	32	21	10																																
29	88	77	66	55	44	34	23	13	3																															
30	89	78	67	56	46	36	26	16	6																															
31	89	78	68	58	47	37	28	18	8																															
32	89	79	69	59	49	39	30	20	11	2																														
33	90	80	70	60	51	41	32	23	14	5																														
34	90	81	71	62	52	43	34	25	16	8																														
35	91	81	72	63	54	45	36	27	19	10	2																													
36	91	82	73	64	55	46	38	29	21	13	5																													
37	91	83	74	65	57	48	40	31	23	15	7																													
38	91	83	75	66	58	50	42	33	25	17	10	2																												
39	92	83	75	67	59	51	43	35	27	20	12	5																												
40	92	83	75	68	60	52	45	37	29	22	15	7	0																											
41	92	84	76	69	61	54	46	39	31	24	17	10	3																											
42	92	85	77	69	62	55	47	40	33	26	19	12	5																											
43	92	85	77	70	63	55	48	42	35	28	21	14	8	1																										
44	93	85	78	71	63	56	49	43	36	30	23	16	10	4																										
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6																										
46	93	86	79	72	65	58	52	45	39	32	26	20	14	8	2																									
47	93	86	79	72	66	59	53	46	40	34	28	22	16	10	5																									
48	93	86	79	73	66	60	54	47	41	35	29	23	18	12	7	1																								
49	93	86	80	73	67	61	54	48	42	36	31	25	19	14	9	3																								
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5	0																							
51	94	87	81	75	68	62	56	50	45	39	34	28	23	17	12	7	2																							
52	94	87	81	75	69	63	57	51	46	40	35	29	24	19	14	9	4																							
53	94	87	81	75	69	63	58	52	47	41	36	31	26	20	16	10	6	1																						
54	94	88	82	76	70	64	59	53	48	42	37	32	27	22	17	12	8	3																						
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	14	9	5	0																					
56	94	88	82	76	71	65	60	55	50	44	39	34	30	25	20	16	11	7	2																					
57	94	88	82	77	71	66	61	55	50	45	40	35	31	26	22	17	13	8	4																					
58	94	88	83	77	72	66	61	56	51	46	41	37	32	27	23	18	14	10	6	1																				
59	94	89	83	78	72	67	62	57	52	47	42	38	33	29	24	20	16	11	7	3																				
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1																			
61	94	89	84	78	73	68	63	58	54	49	44	40	35	31	27	22	18	14	10	7	3																			
62	94	89	84	79	74	69	64	59	54	50	45	41	36	32	28	24	20	16	12	8	4	1																		
63	95	89	84	79	74	69	64	60	55	50	46	42	37	33	29	25	21	17	13	10	6	2																		
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30	26	22	18	15	11	7	4	0																	
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2																	
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32	29	25	21	17	14	10	7	3	0																
67	95	90	85	80	75	71	66	62	58	53	49	45	41	37	33	30	26	22	19	15	12	8	5	2																
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	31	27	23	20	16	13	10	6	3																
69	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	32	28	24	21	18	14	11	8	5	1															
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3															
71	95	90	86	81	77	72	68	64	60	56	52	48	45	41	37	33	30	27	23	20	17	13	10	7	4	1														
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38	34	31	28	24	21	18	15	12	9	6	3														
73	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39	35	32	29	25	22	19	16	13	10	7	4	1													
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39	36	33	29	26	23	20	17	14	11	8	5	3													
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1												
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11	8	5	3												
77	96	91	87	83	79	74	71	67	63	59	56	52	48	45	42	39	35	32	29	26	23	20	17	14	12	9	6	4												
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33	30	27	24	21	18	16	13	10	8	5												
79	96	91	87	83	79	75	71	68	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	17	14	11	9	6												
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15	12	10	7	5	3	0									
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45	42	39	36	33	30	28	25	22	20	17	14	12	10	7	5	2	0								
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46	43	40	37	35	32	29	26	24	21	19	16	14	12	9	7	5	3	0							
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47	44	42	39	36	33	31	28	26	23	21	18	16	14	11	9	7	5	3	1						
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48	46	43	40	37	35	32	30	27	25	22	20	18	15	13	11	9	7	5	3	1					
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5	3	1				
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	48	45	42	40	37	35	32	30	28	25	23	21	19	17	15	13	11	9	7	5	3	1			
94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46	43	41	38	36	33	31	29	27	24	22	20	18	16	14	12	10	9	7	5	3	1		
96	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	35	32	30	28	26	24	22	20	18	16	14	12	10	8	7	5	3	2	0
98	96	93	89	86	83	79	76	73	70	67	64	61	58	56	53	50	48	45	43	40	38	36	34	32	29	27	25	23	21	19	17	15	14	12	10	8	7	5	3	2
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13	12	10	8	7	5	4
102	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55	52	49	47	45	42	40	38	36	34	32	30	28	26	24	22	20	18	16	15	13	11	10	8	7	5
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106	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	36	34	32	30	28	26	24	23	21	19	17	16	14	13	11	10	8
108	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57	54	52	49	47	45	43	41	39	37	35	33	31	29	27	25	24	22	20	19	17	16	14	12	11	10
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	44	42	40	38	36	34	32	30	28	26	25	23	21	20	18	17	15	14	12	11
112	97	94	90	87	84	81	79	76	73	70	68	65	63	60	58	55	53	51	49	47	44	42	40	38	36	35	33	31	29	27	26	24	23	21	19	18	16	15	14	12
114	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	56	54	52	49	47	45	43	41	39	37	35	34	32	30	28	27	25	24	22	20	19	18	16	15	13
116	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54	52	50	48	46	44	42	40	38	36	34	33	31	29	28	26	25	23	22	20	19	17	16	14
118	97	94	91	88	85	82	79	77	74	72	69	67	64	62	59	57	55	53	51	49	47	45	43	41	39	37	35	34	32	30	29	27	25	24	23	21	20	18	17	16
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	47	45	43	41	40	38	36	34	33	31	29	28	26	25	23	22	21	19	18	17
122	97	94	91	88	85	83	80	77	75	72	70	67	65	63	60	58	56	54	52	50	48	46	44	42	40	39	37	35	34	32	30	29	27	26	24	23	22	20	19	18
124	97	94	91	88	85	83	80	78	75	73	70	68	65	63	61	59	57	54	52	50	48	47	45	43	41	39	38	36	34	33	31	30	28	27	25	24	22	21	20	18
126	97	94	91	88	86	83	80	78	75	73	70	68	66	64	61	59	57	55	53	51	49	47	45	44	42	40	38	37	35	33	32	30	29	27	26	25	23	22	21	19
128	97	94	91	88	86	83	81	78	76	73	71	68	66	64	62	60	58	56	54	52	50	48	46	44	42	41	39	37	36	34	33	31	30	28	27	25	24	23	22	20
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	50	48	47	45	43	41	40	38	37	35	33	32	30	29	28	26	25	24	22	21
132	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	58	56	55	53	51	49	47	45	44	42	40	39	37	36	34	33	31	30	28	27	26	24	23	22
134	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	51	49	48	46	44	43	41	39	38	36	35	33	32	30	29	28	26	25	24	23
136	97	94	92	89	86	84	81	79	77	74	72	70	68	65	63	61	59	57	55	54	52	50	48	46	45	43	41	40	38	37	35	34	33	31	30	28	27	26	25	23
138	97	94	92	89	87	84	82	79	77	75	72	70	68	66	64	62	60	58	56	54	52	50	49	47	45	44	42	40	39	37	36	35	33	32	30	29	28	27	25	24
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58	56	54	53	51	49	47	46	44	43	41	40	38	37	35	34	32	31	30	29	27	26	25
142	97	95	92	89	87	84	82	80	77	75	73	70	68	66	64	62	60	58	57	55	53	51	49	48	46	44	43	42	40	39	37	36	34	33	32	30	29	28	27	26
144	97	95	92	89	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	53	52	50	48	47	45	44	42	41	39	38	36	35	34	32	31	30	29	27	26
146	97	95	92	90	87	85	82	80	78	75	73	71	69	67	65	63	61	59	57	56	54	52	50	49	47	45	44	43	41	40	38	37	36	35	33	32	30	29	28	27
148	97	95	92	90	87	85	82	80	78	76	73	71	69	67	65	63	61	60	58	56	54	53	51	49	48	46	45	43	42	40	39	38	36	35	34	32	31	30	29	28

NOTE:—The temperature depressions given in these tables strictly apply only when the wet bulb is subjected to a current of air with a velocity of not less than 15 ft. per second.

How to use table—Example—Air temperature (dry bulb) in left hand column reads 110° F. Wet bulb reads 10° F. below dry bulb (see top row of figures across page). Humidity is 70%.

PERSONALIZED
HEATING CONTROL
for
APARTMENTS

SECTION IX

Printed in U.S.A.

Personalized Apartment Heating

A LOGICAL DEVELOPMENT

THOSE CONCERNED with the construction and operation of the modern apartment building have made great strides in exterior design and interior comfort, as well as beauty of appointment. Each new building adds something to create more of the atmosphere of the individual home. This is true regardless of the size of the apartment.

However, in the control of heating, the apartment building has lagged behind the home and the industrial building. The fundamental policy has been to furnish enough heat to the entire building to maintain all apartments at the temperature level of the apartment whose occupants desire the highest temperature. The result has been overheating of the remainder of the building, with the only remedy shutting off radiators or opening windows, which naturally wastes heat.

A recent independent survey of apartment tenants conducted by Ross Federal Research Corporation in larger centers of population in the United States confirms the fact that most tenants would welcome the possibility of personal control of their heating requirements, so that the tenant who is comfortable at 68 degrees can maintain that temperature, while the tenant who demands 75 degrees can also be comfortable. Specifically, 84.5% of tenants interviewed stated that Individual or Personalized Apartment Heating was either necessary or desirable. Minneapolis-Honeywell Personalized Heating control, by the proper placing of a thermostat with companion devices, can provide exactly this individual control.

ADVANTAGES OF PERSONALIZED CONTROL TO OWNERS OR OPERATORS

• COMFORT

It is the desire of all apartment operators to maintain their tenants in comfort, because over and above every other consideration, bodily comfort is essential to the maintenance of a successful lease. The owner or operator who offers M-H Personalized Apartment Control will have a distinct advantage in the competitive struggle for tenants in the post war era.

• ECONOMY

Definite economies will result from M-H Personalized Control because each apartment is maintained at exactly the desired temperature without overheating or underheating regardless of variations in outdoor temperatures, wind-velocities, or sun intensity. It is not necessary to overheat most of the building in order to satisfy the coldest apartment or the tenant who desires the highest temperature.

• NEW OR OLD BUILDINGS

M-H Personalized Control is adaptable to either new or existing apartment buildings. In new buildings, the heating layout should be arranged during the planning stage to permit the application of M-H Personalized Control with the lowest overall expense for both heating and control. Existing apartment buildings may, in nearly every case, be modernized with M-H Personalized Control with the same advantages as in new buildings.

• SATISFIED TENANTS

The general result of making the tenant responsible for his own apartment temperatures with resulting increased heating comfort, will naturally result in greater satisfaction to the tenant and greater health for him and his family.

• RENTABILITY

The sum total of furnishing this added comfort in the form of M-H Personalized Control adds up to greater rentability in a building so equipped. The shrewd and far-seeing owner or operator who realizes the possibilities inherent in M-H Personalized Apartment Control system will find himself in the fortunate position of having his building rented, while others go begging for tenants. The fact that 48.2% of tenants interviewed in the aforementioned survey stated they would be willing to pay up to $10 additional monthly rental proves this point.

• LONGER LEASES

The satisfied tenant does not want to move. Minneapolis-Honeywell is certain, from the surveys it has made, that Personalized Heat Control will be an important factor in maintaining long tenancies, obviating the usual May 1 and September 1 upheavals. Of the tenants interviewed, 61% stated that they preferred Individual or Personalized Heating Control to such other features as electric dishwasher, breakfast nook or artificial fireplace.

• WAITING LISTS

There is nothing more satisfying to the owner or operator of an apartment than a long waiting list. Installation of the M-H system of personalized control, more than any other single thing since mechanical refrigeration became universal in apartments, will be a dominant influence in attracting tenants to your building.

• NO VACANCIES

In a Building with Personalized Heating Control, the temperature in each apartment is individually controlled by the occupant. Each tenant can select exactly the temperature he desires. It goes without saying that there will be less vacancies in an apartment building with Personalized Heating Control, than one without individual control . . . and fuel will not be wasted by tenants opening the windows because they are too warm. The building to the right, on the other hand, does not have Personalized Heating, with the result that apartments are usually available. Some tenants are too warm—others are too cold. As an apartment operator, you can draw your own conclusions as to the desirable building.

FACTORS THAT PERSONALIZED CONTROL WILL OVERCOME

• INDIVIDUAL REQUIREMENTS

The most important factor in satisfying the tenant of an apartment is the consideration of individual requirements of himself and those who live with him. Under this heading the Number One factor is heating. It stands to reason that a system giving the tenant individual control of his apartment temperature will create a greater satisfaction the year around than present practices in apartment heating. Individual tastes, heat demands due to differences in age, etc. all can be satisfied with M-H Personalized Heating Control. Each tenant may live in temperatures kept at his own liking.

It takes all kinds of people to make up the world, and the same is true in any apartment building. Tenant "A", for example, likes to maintain his apartment at 70°, but tenant "B" on the other hand, insists upon 75°. Obviously, a compromise will not do. In order to satisfy tenant "B" with 75°, you overheat tenant "A", so that he either turns off his radiators or opens his windows and wastes fuel. The answer, of course, is Individual or Personalized Heating, controlled by Minneapolis-Honeywell, which enables every tenant to have exactly the temperature he needs or desires. Apartment temperatures are always maintained at the desired comfort level.

• SOLAR RADIATION

This is a factor that is very important in buildings with large outside areas. If the sun is shining on one side of an apartment building, the apartments on that side, naturally, require less heat during the sunny period than apartments on the side not so affected. Under M-H Personalized Heating Control the thermostats on that side of the building will reduce the heat in-put to prevent over heating. Temperatures will be held at the comfort level, which will result in greater economy in the operation of the heating plant.

• WIND VELOCITY

This is a factor directly opposite in its effect to solar radiation. The side of the building struck by a cold wind will require more heat than a section not so affected, but the thermostats in apartments in such an area will compensate for the additional heat required in these apartments.

• CONSTRUCTION

Although the construction throughout an apartment building is usually the same, any differences will make uniform heating more difficult. Also, in tall buildings the tendency of heat to rise may cause the upper floors to overheat and the lower floors to underheat. M-H Personalized Control will automatically compensate for these differences in heating requirements.

• TIMES OF OCCUPATION

This, like "Individual Requirements," is a personal matter. Under individual apartment control, tenants can be encouraged to maintain their apartments at lower temperatures during unoccupied periods, which will result in greater economy in the operation of the apartment heating system. This factor can be made a very important item, if the tenants are properly educated to take advantage of it.

• M-H PERSONALIZED CONTROL IS INEXPENSIVE

The investment in the control installation will represent only a very small percentage of the total cost of an apartment building—and the return on this small additional investment will be far greater than the normal return on the entire building because of the added tenant satisfaction, longer leases, and elimination of vacancies, in addition to a direct return due to fuel savings.

• FUEL SAVINGS

In a survey of a number of typical apartment buildings, it was determined that the normal temperatures desired were:

10% desired 76 degrees or more
80% desired 72 degrees
10% desired 70 degrees or less

Without individual apartment control, it would be necessary to maintain the entire building at a minimum of 76 degrees in order that all tenants are satisfied. If any of the tenants desiring 76 degrees or more are located on the north or windy side of the building, the temperatures in the apartments on the south or protected side of the building may reach or exceed 80 degrees. Yet the average temperature required in the entire building would be only 72.2°.

When an apartment is heated beyond the desired temperature, it is seldom that the tenant will close the radiator valves. In nearly every case, he will open windows and the excess heat is lost to the outdoors.

Tests run on a large number of buildings in all parts of the country show that an average fuel saving

of 20% may be expected when adequate automatic controls are used and that larger fuel savings often result from their use.

• MAINTENANCE

The thermostats, control valves and other equipment used in the application of M-H Personalized Heating Control have been designed for long life and trouble-free operation. Actual experience with these controls on thousands of installations of all types prove that the maintenance cost amounts to almost nothing at all. Once this control equipment has been installed and adjusted, it will operate for years with little or no attention. M-H Personalized Control may be completely automatic so that no manual attention is required.

• NIGHT SHUTDOWN

May be provided for the apartment building as a whole through the use of a central control panel or in each individual apartment through the use of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats. In either case the temperature may be reduced at night and raised in the morning at the exact times desired. The change between day and night operation is completely automatic requiring no manual attention. This is described in detail later in this bulletin.

• EDUCATING THE TENANT

Since the thermostats used in M-H Personalized Heating Control are as simple as those used in millions of modern homes today, the tenant will understand their adjustment very quickly. A simple explanation of their operation when a tenant first moves in is all that is necessary. The temperature adjustment may be locked at a fixed point or the maximum setting of the thermostats may be limited when this is desired by the apartment house owner for greatest economy. M-H Personalized Control is the silent servant of the apartment house owner or operator.

• REPRESENTATIVE INSTALLATION

M-H Personalized Heating Control is not new. It has been used for a number of years in apartment buildings all over the country.

Following is a typical apartment building which is equipped with M-H Personalized Heating Control.

> 1609 NORTH PROSPECT AVENUE Apartment Building
> Milwaukee, Wisconsin
>
> Mr. Ogden, property manager, says after two years of study:
>
> "INDIVIDUAL CONTROLS HELP SELL APARTMENTS . . . . KEEPS TENANTS SATISFIED."

This modern apartment building erected and completed just before the war, was equipped at time of construction, with M-H Personalized Heat Control.

Pneumatic equipment was decided upon as the most adaptable. One thermostat is used in each of the 55 apartments. One zone valve controls the hot water supply to each separate apartment—so that different temperatures can be maintained in the separate apartments to fulfill the individual tenant's requirements.

A hot-water, one-pipe system was installed and the piping arranged so that the valve for each apartment could be used to control heat output to the apartments individually. Four sets of risers were located in the center section of building and the radiation in each apartment was connected by horizontal piping at the different floor levels. These lateral pipes were enclosed in a sheet metal case at the baseboard of the rooms on outside walls. This method of enclosing the lateral pipes was very economical and proved to be very satisfactory.

Mr. Ogden's experience with Personalized Control, concerning tenant reaction, fuel costs, and maintenance are typical. A complete success—would perhaps best describe his experience.

Another typical apartment that is equipped with M-H Personalized Heating Control.

> KENT COURT . . . . Summit, New Jersey
>
> Mr. Rinhart, after five years experience with M-H Personalized Heating Control says:
>
> "HIS TENANTS UNDERSTAND and appreciate individual apartment control—some have said they would never live in another apartment without a thermostat."

Architectural Forum, in a recent issue, describes "Kent Court" as "The most talked about apartment in the state." Such features as individual full basements, stall showers as well as bath-tubs and individual heat control of apartments, are described in the article.

The design carries out the two-story with basement or duplex type of apartment. Each apartment has a living room, dinette and kitchen on the first floor and two bedrooms and a bath on second floor. On a living room wall in each apartment will be found an electric thermostat.

Each of the three buildings in the group has a steam boiler with a one-pipe steam system. Located in basement of each apartment at the take-off from the main loop is a motorized valve which is actuated from the corresponding individual room thermostat.

Mr. Rinhart's letter gives the management's experience and the tenants' answer to Personalized Control in full—after five full years of operation. This type of control is to be used as standard in all of their post war apartments.

HERE IS HOW IT IS DONE . . . .

A new apartment building can be easily provided with Personalized Apartment Heating if each individual apartment is designed to include one of the following types of automatic temperature control systems:

(1) Individual Apartment Control

(2) Sectional Control of Individual Apartments

(3) Individual Room Control

These three types of control systems are described and illustrated in the pages that follow.

The flexibility of the Minneapolis-Honeywell Control Systems for apartments will be apparent after all their possibilities are more fully understood. Any of the above systems, for example, may consist of "modulating" or "two position" thermostats and valves as best suits the particular heating system. Minneapolis-Honeywell further offers either electric, pneumatic (air operated), or combination pneumatic-electric systems of control. The problem of selecting one or the other of these systems to the best advantage of the Apartment Building owners, operators and tenants is usually a fairly simple one if you will call upon the services of the M-H engineers in your vicinity. They will be glad to help with your problem of Personalized Heating.

INDIVIDUAL APARTMENT CONTROL

New apartment buildings can be planned so that the individual apartment is served by a separate branch from the heating main, as illustrated, to facilitate individual apartment control. A thermostat located in the living room controls a motorized valve in the separate supply line to all the radiators of the apartment. Thus each tenant may keep his apartment at the temperature level that best satisfies him,—not only by day but during the night as well.

This system provides an inexpensive but extremely desirable control arrangement for new apartment buildings. It is not readily adapted to most existing apartments because it requires extensive piping changes.

SECTIONAL CONTROL OF THE *Individual* APARTMENT

Sectional Control of individual apartments, as illustrated, provides means of incorporating rooms of like usage and temperature requirements under control of their individual thermostat and control valve. The living area is served by a heating main separate from the heating main serving the sleeping quarters. This permits control of the temperature in either area at just the right level to suit individual needs.

While two sections of control as illustrated would satisfy the majority of installations, additional sections of control may be provided where required. Apartments, for example, arranged for servants' quarters should have the service area under control of a separate thermostat and control valve.

This type of control, while applicable to apartments of any size, finds its widest and most logical application in apartments of six or more rooms.

INDIVIDUAL ROOM CONTROL

Individual Room Control, as illustrated, is nearly always the most satisfactory and flexible system of control for any type of building using any type of heating system. Each room is provided with a thermostat which controls only the radiator or radiators in the respective room. Thus any room may be kept at exactly the temperature its occupants desire or its use demands. Any room or group of rooms may be kept at a lower more economical level when unoccupied.

Individual room control can usually be applied to existing apartments as well as new, since as a rule, no piping changes in the heating mains are required.

Individual room control is equally applicable to small or large apartments—the cost being almost directly proportional to the number of radiators controlled.

PERSONALIZED APARTMENT HOUSE HEATING CONTROL COMPETITION

On September 1, 1943, Minneapolis-Honeywell announced a Personalized Apartment Heating Control Design Contest. Prizes totalling $10,000 were offered and the competitors were asked to submit piping and control layouts involving the use of either steam or hot water. A set of four plans of a typical six story apartment building was sent to each competitor including plan views of a typical floor, the basement, and the penthouse, a sectional view of the building, and an isometric view of a typical floor.

More than two thousand requests were received for plans and 513 submissions were received before the closing date on November 15, 1943. Twenty-six prizes were awarded to the contestants.

The submittals indicated a trend from steam to hot water and an increased interest in radiant heating.

SUMMARY OF SUBMITTALS

1 Pipe Steam	63
2 Pipe Steam	158
1 Pipe Hot Water	114
2 Pipe Hot Water	126
Steam Radiant	7
Hot Water Radiant	45
Total	513

JUDGES FOR THE CONTEST WERE . . .

Edward E. Ashley
Consulting Engineer
New York City

John W. Root
Holabird and Root—Architects
Chicago, Illinois

John E. Haines
Minneapolis-Honeywell Regulator Co.
Minneapolis, Minnesota

THE SIX MAJOR WINNERS were as follows:

Hot Water Heating Systems

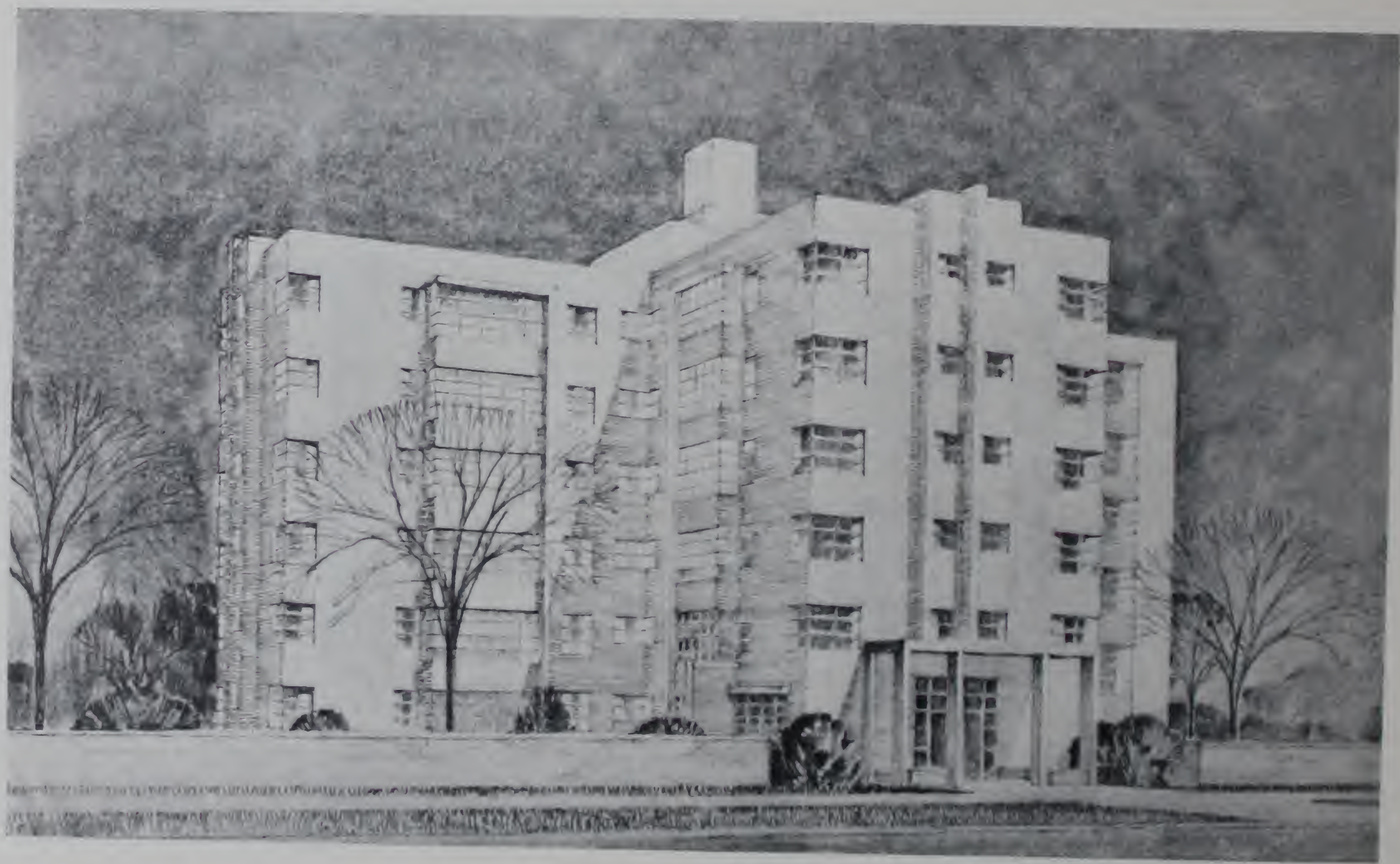
Leonard Weger—Philadelphia, Pa.
Walter T. Rolfe—Austin, Texas
J. A. MacWilliams & A. D. Rubin—Perth Amboy, N. J.

Steam Heating Systems

Clyde H. Baker—Detroit, Michigan
Paul E. Nystrom—Madison, Wisconsin
Abraham Walton—Jersey City, N. J.

In the following pages are shown eight of the winning designs which illustrate a variety of piping and control layouts for apartment buildings.

Below is an Exterior View of the Competition Building.



In presenting these typical piping and control layouts it is believed that they will be of assistance to architects and engineers in determining the proper manner in which to lay out the piping and control systems in apartment buildings under design.

Although minor changes and corrections have been made in the designs as submitted by the contestants, these layouts are not intended to be complete or accurate in every detail.

The control of any of the following layouts may be either electric, pneumatic or a combination of both. Details of control applications are covered in the engineering section of this booklet.

LAYOUT NO. 1

Type of Heating System—2 Pipe Steam

Piping Layout—22 Supply Risers
22 Return Risers

Control—

One Room Apartments

One thermostat located in the living room controls the radiator valve on the radiator in that room only.

Kitchen and bathroom radiators are not automatically controlled.

One and Two-Bedroom Apartments

One thermostat in the living room controls individual radiator valves in the living room and dining room. One thermostat in the bedroom controls an individual radiator valve in that room.

Kitchen and bathroom radiators are not automatically controlled.

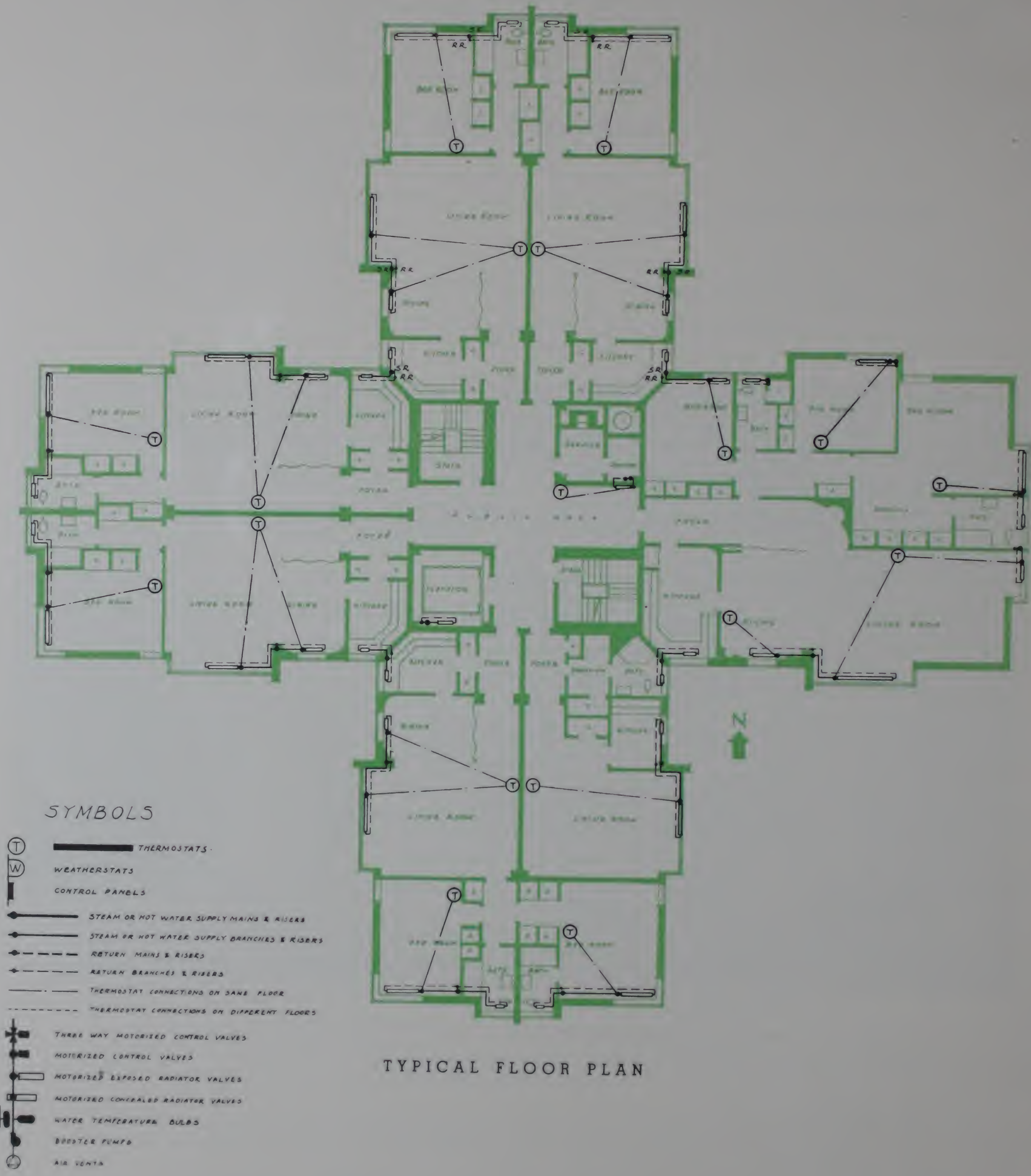
Three-Bedroom Apartments

Same control setup as in other bedroom apartments.

Night Control—

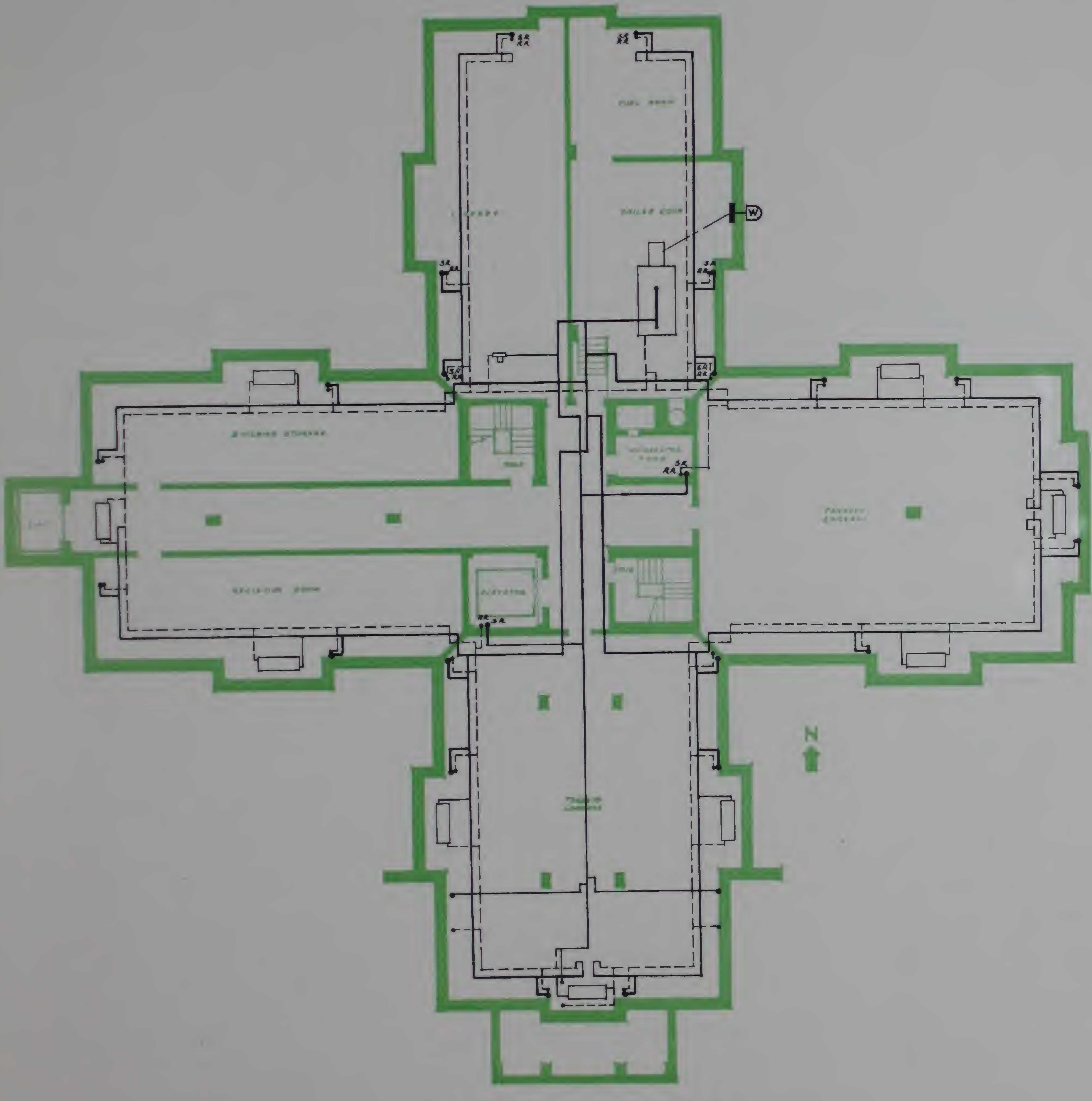
Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 1



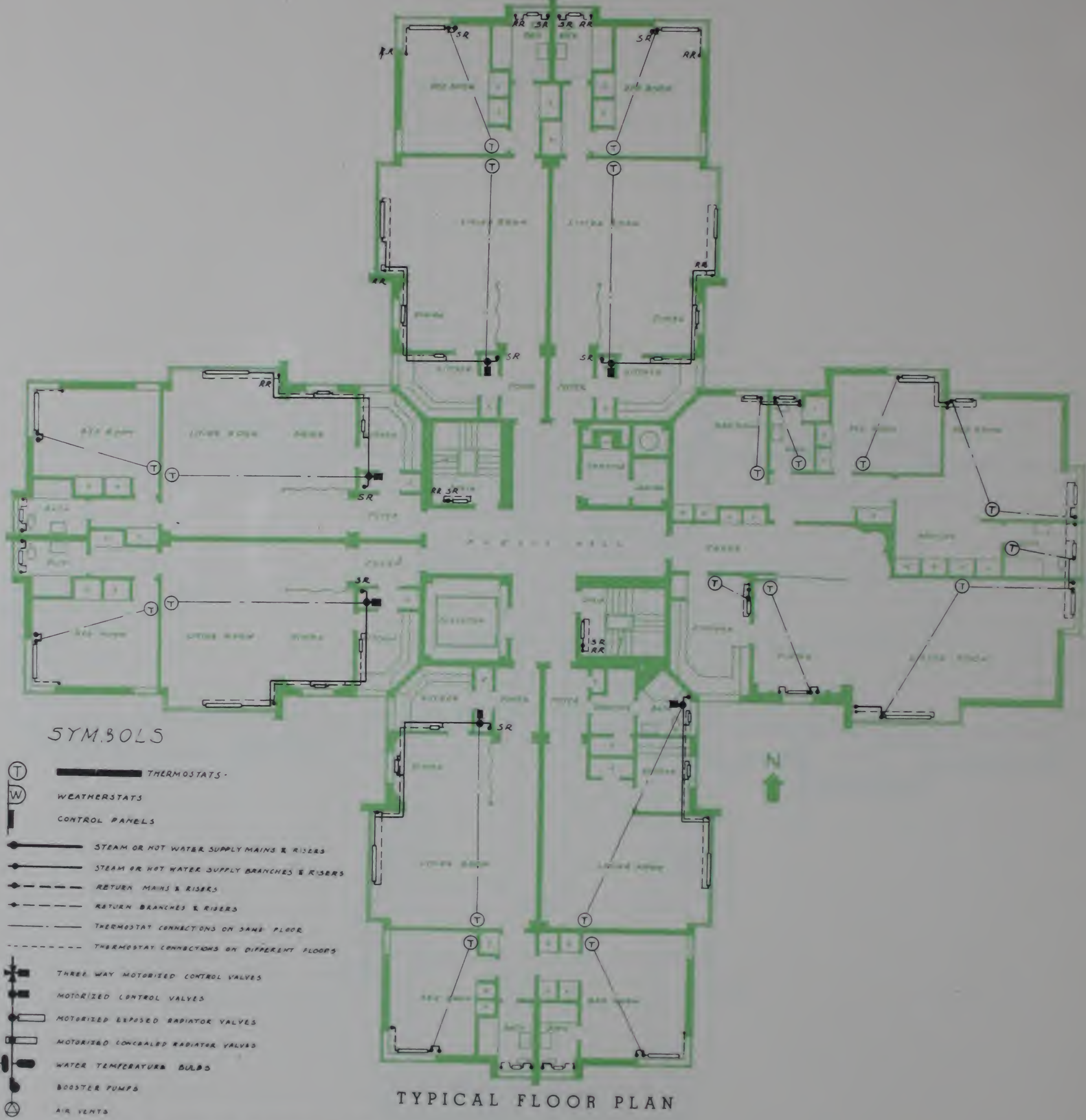
TYPICAL FLOOR PLAN

LAYOUT NO. 1



BASEMENT FLOOR PLAN

LAYOUT NO. 2



TYPICAL FLOOR PLAN

Type of Heating System—2 Pipe Steam

Piping Layout—27 Supply Risers
26 Return Risers

Control—

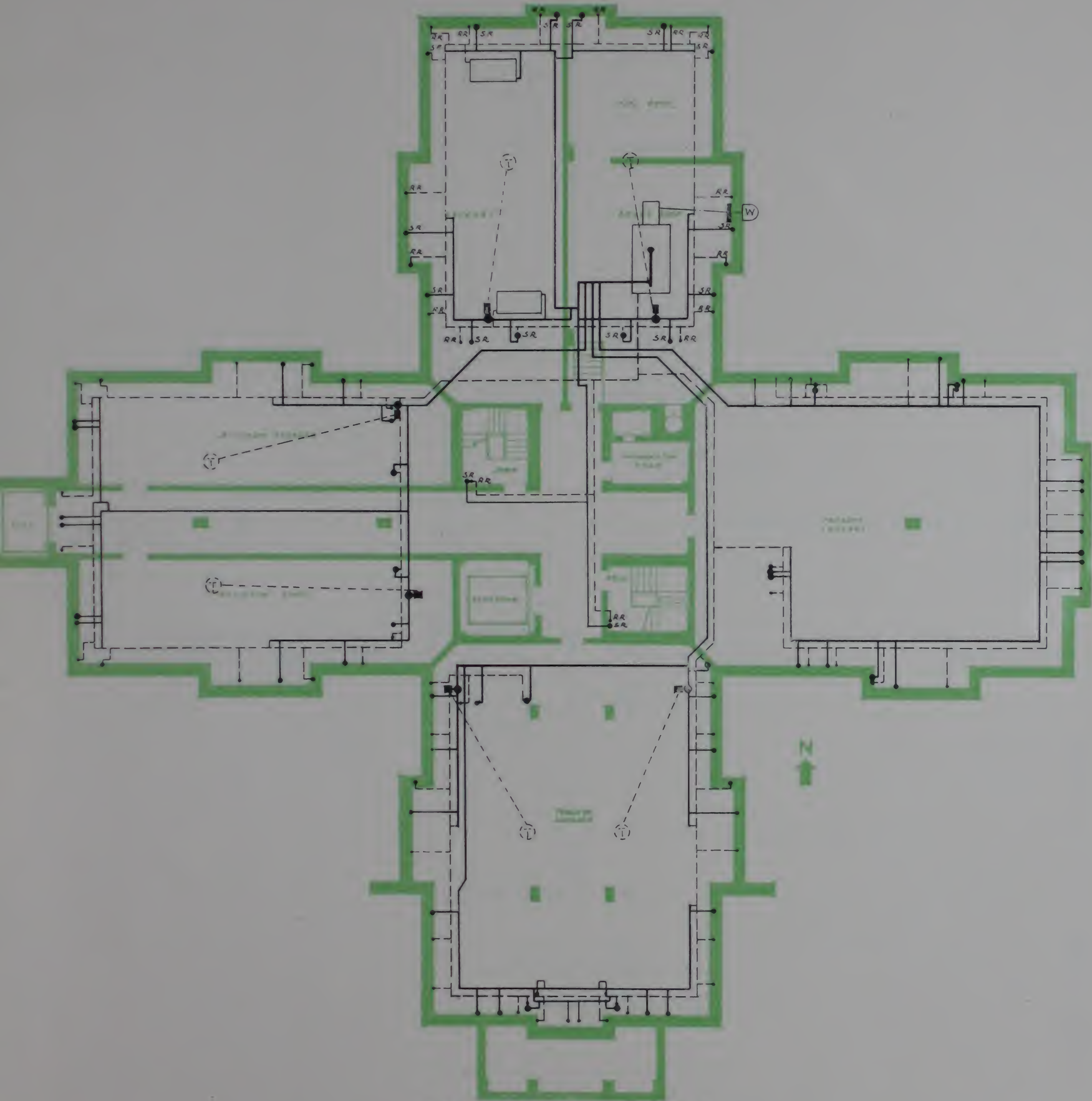
One Room Apartments

One thermostat in the living room controls a valve supplying steam to all radiators.

One and Two-Bedroom Apartments

One thermostat in the living room controls a valve supplying steam to the radiators in the living room, dining room and kitchen. One thermostat in each bedroom controls an individual radiator valve in each bedroom.

LAYOUT NO. 2



BASEMENT FLOOR PLAN

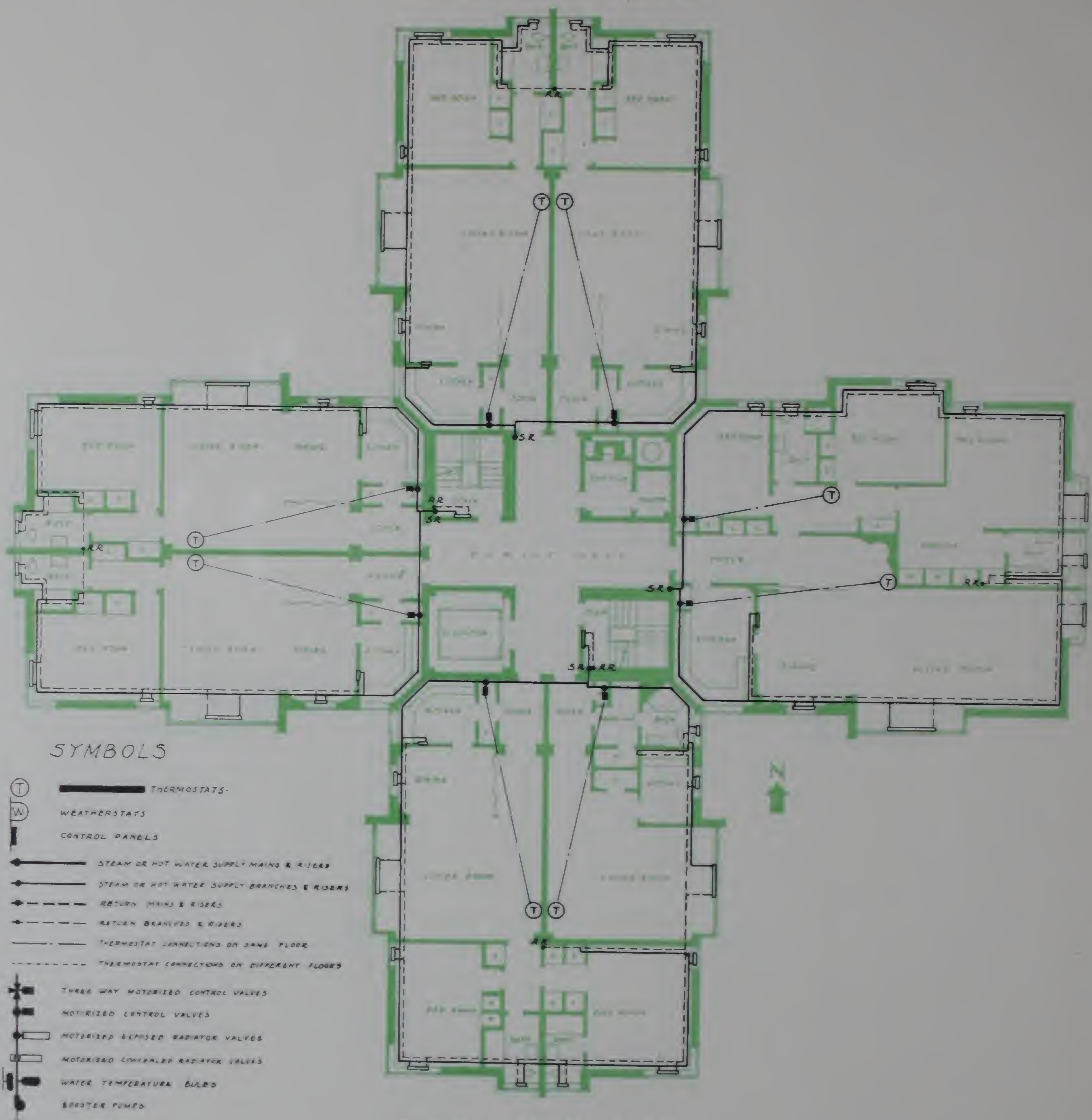
Bathroom radiators are not automatically controlled.

Three-Bedroom Apartments

Individual thermostats located in the living room, dining room, kitchen, each bedroom and bath control individual radiator valves on the respective radiators.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 3



TYPICAL FLOOR PLAN

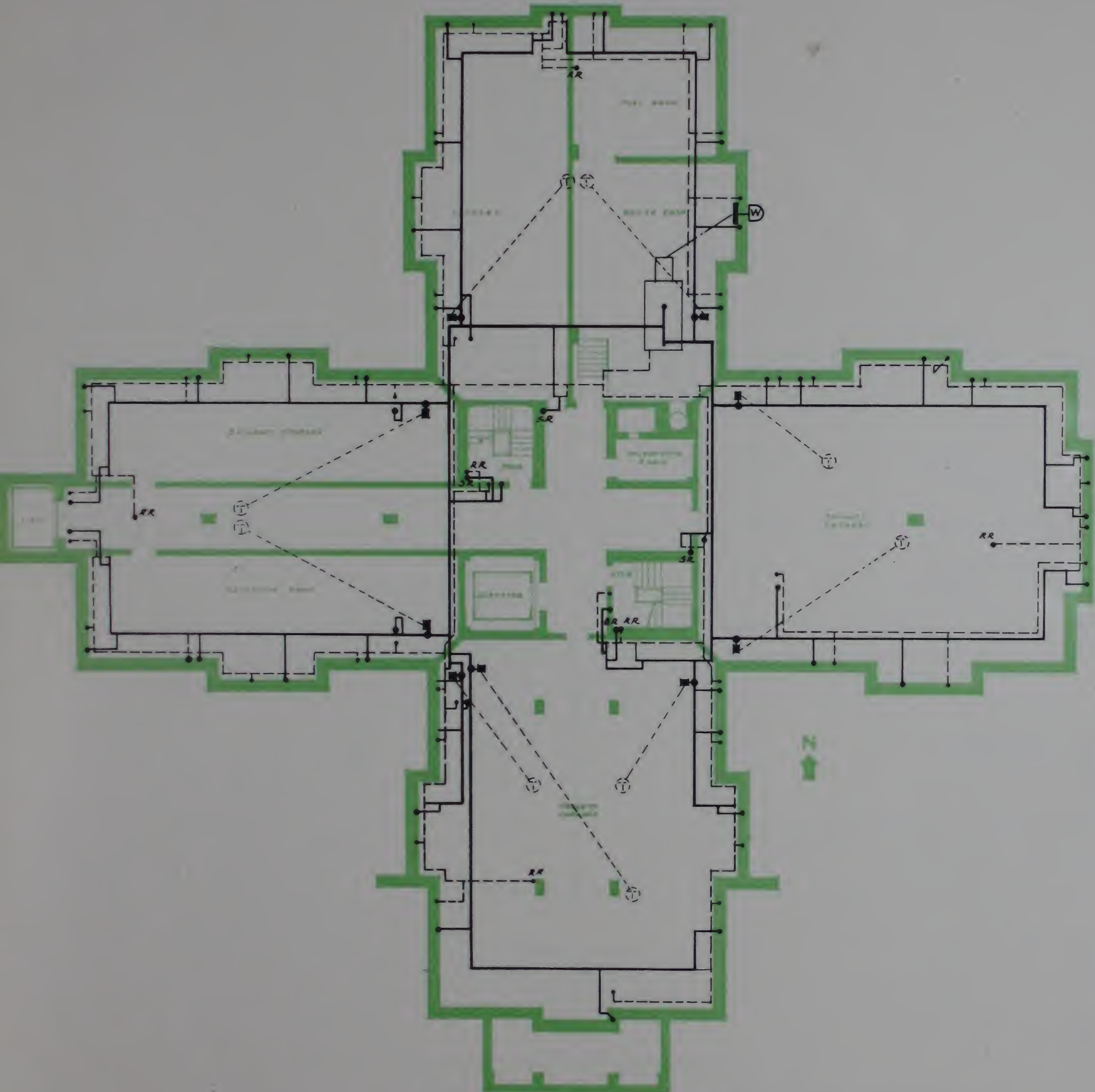
Type of Heating System—2 Pipe Steam

Piping Layout—4 Supply Risers
6 Return Risers

Control—

One thermostat located in the living room of each apartment controls a valve supplying steam to all radiators in each apartment.

LAYOUT NO. 3

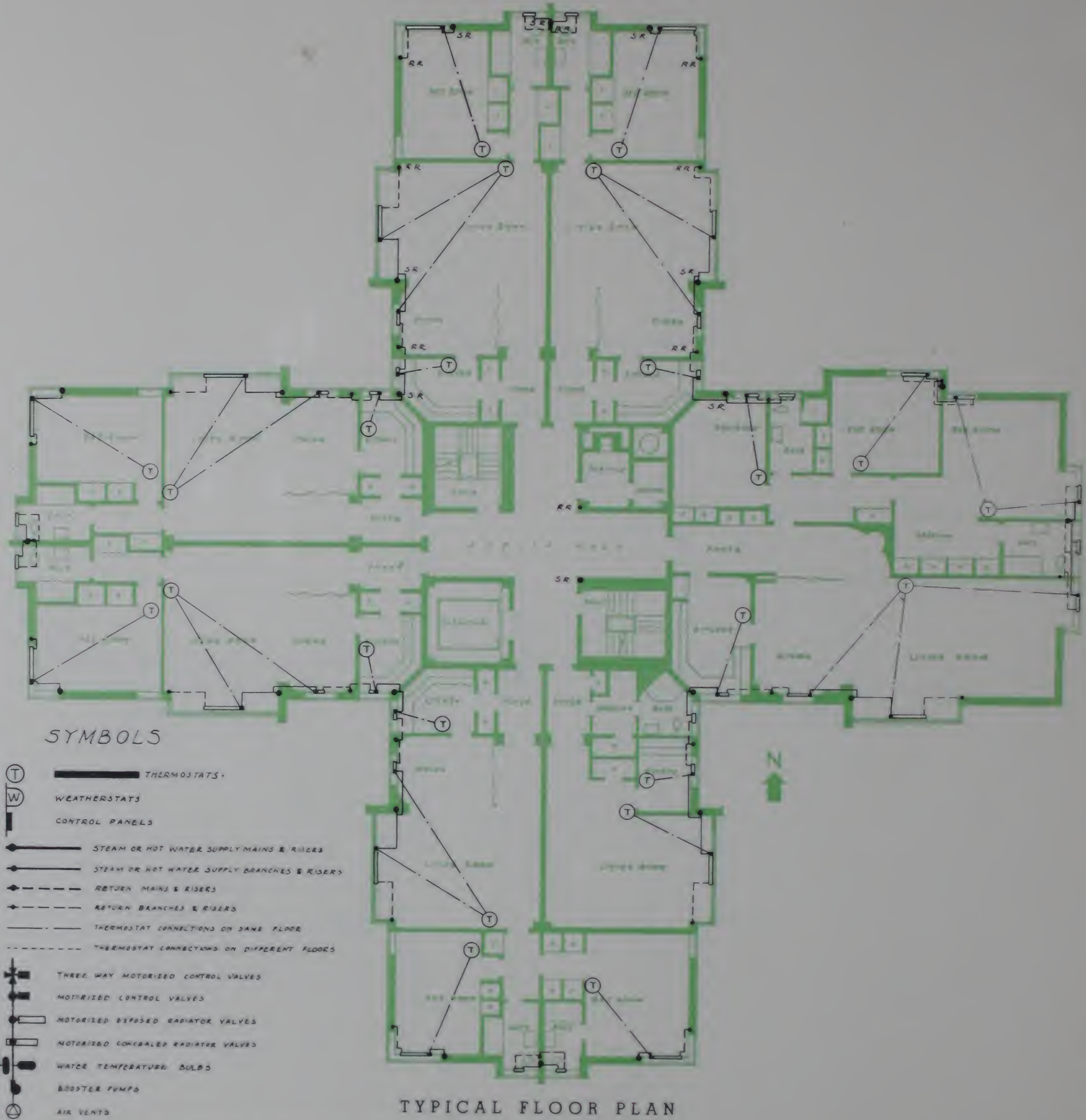


BASEMENT FLOOR PLAN

A second thermostat, in the three bedroom apartments only, located in the hallway between the bedrooms, controls a valve supplying steam to all three bedrooms and both bathrooms.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 4



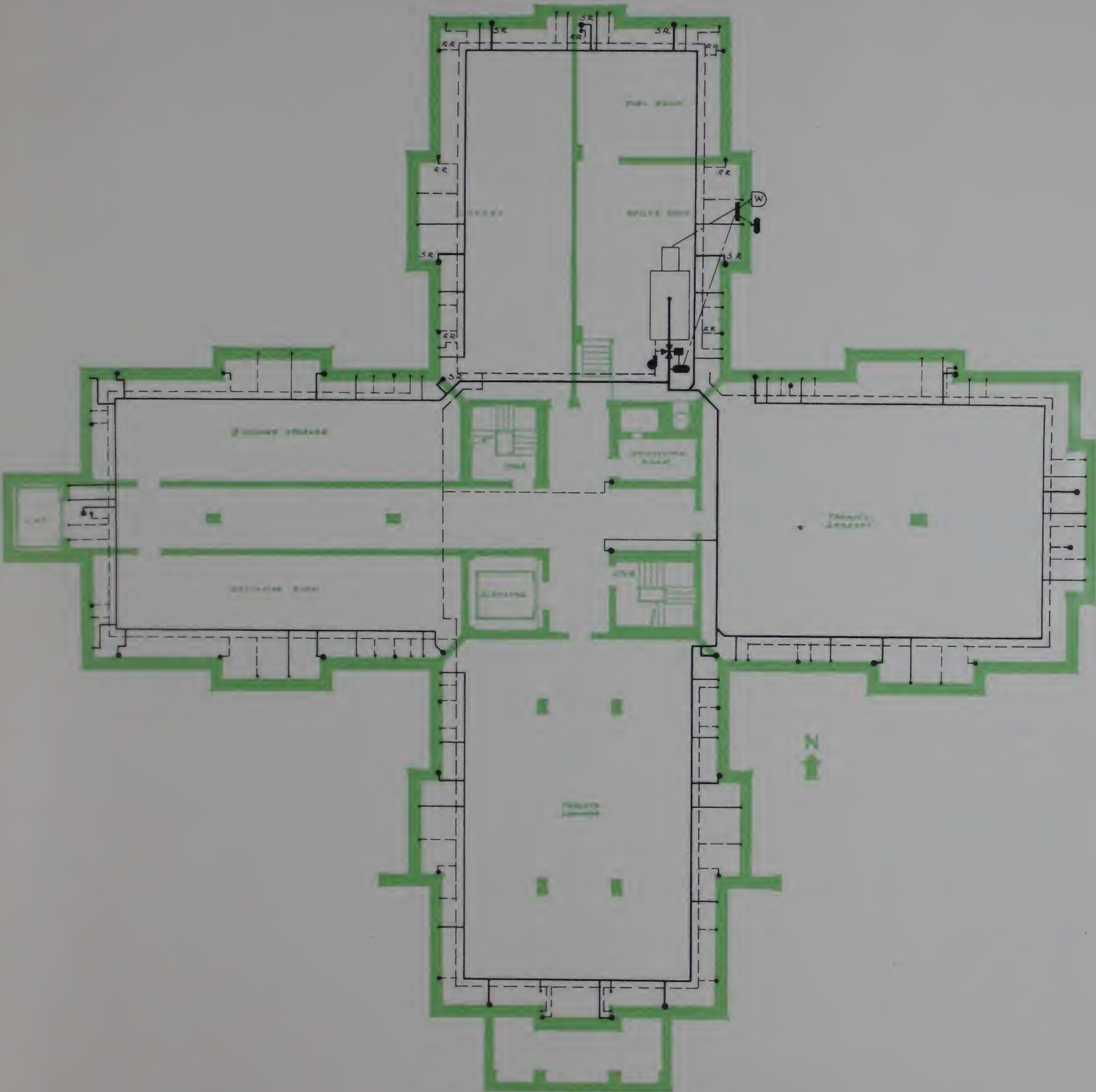
TYPICAL FLOOR PLAN

Type of Heating System—2 Pipe Hot Water

Piping Layout—22 Supply Risers, 26 Return Risers

Control— *One Room Apartments*	One thermostat located in the living room controls an individual radiator valve in that room only. One thermostat located in the kitchen controls an individual radiator valve in that room only. Bathroom radiators are not automatically controlled.
One and Two-Bedroom Apartments	One thermostat located in the living room controls individual radiator valves in the living room and dining room. One thermostat in each bedroom controls an individual radiator valve in each bedroom. Bathroom radiators are not automatically controlled.

LAYOUT NO. 4



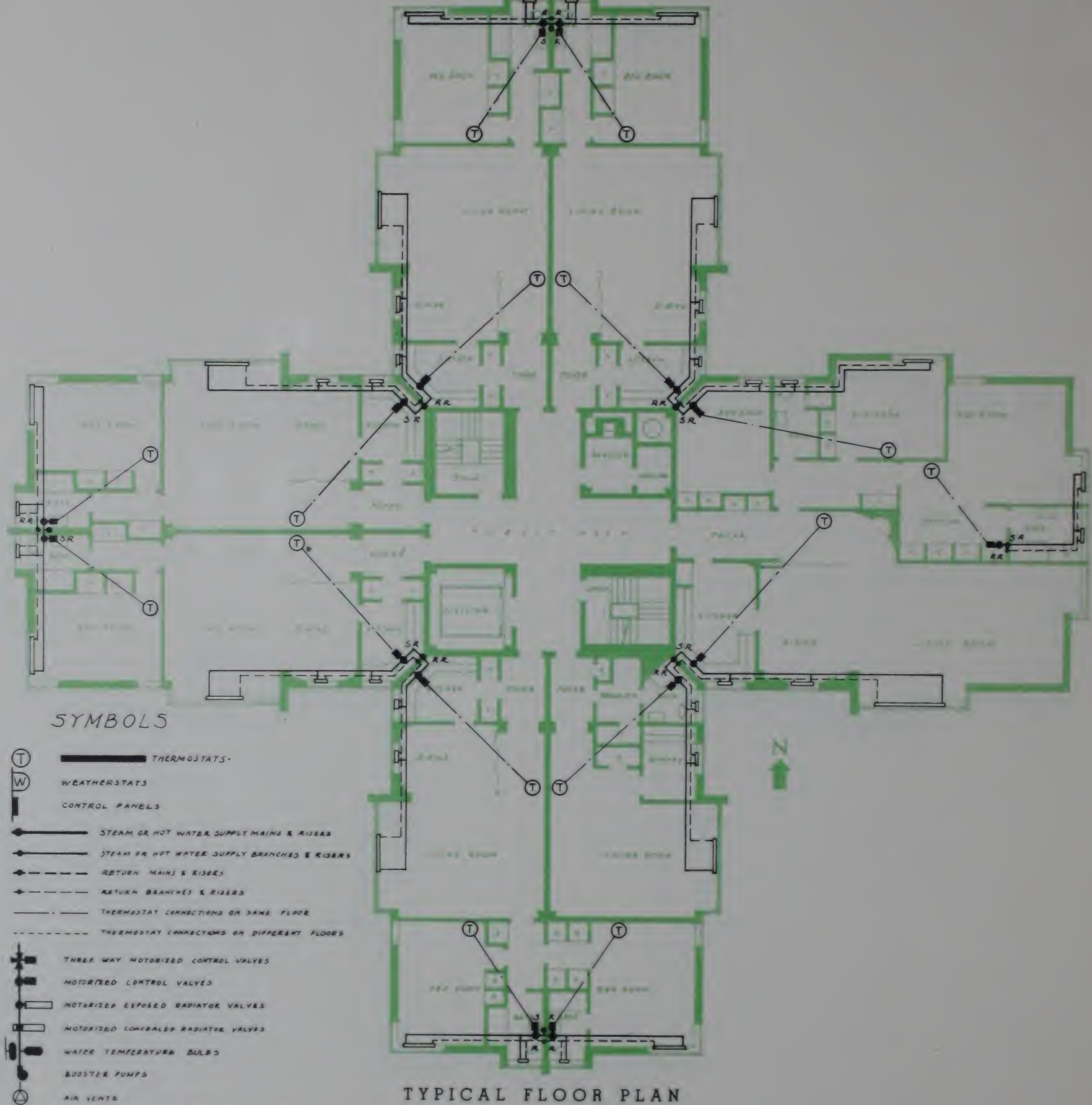
BASEMENT FLOOR PLAN

Three-Bedroom Apartments—Same control setup as in other bedroom apartments.

Outside Controller—A compensated control with one bulb located in the hot water supply line to the radiation provides for hot water to the radiation at predetermined temperatures based upon outdoor temperatures to provide for the greatest fuel economy.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of a clock type electric thermostat or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 5

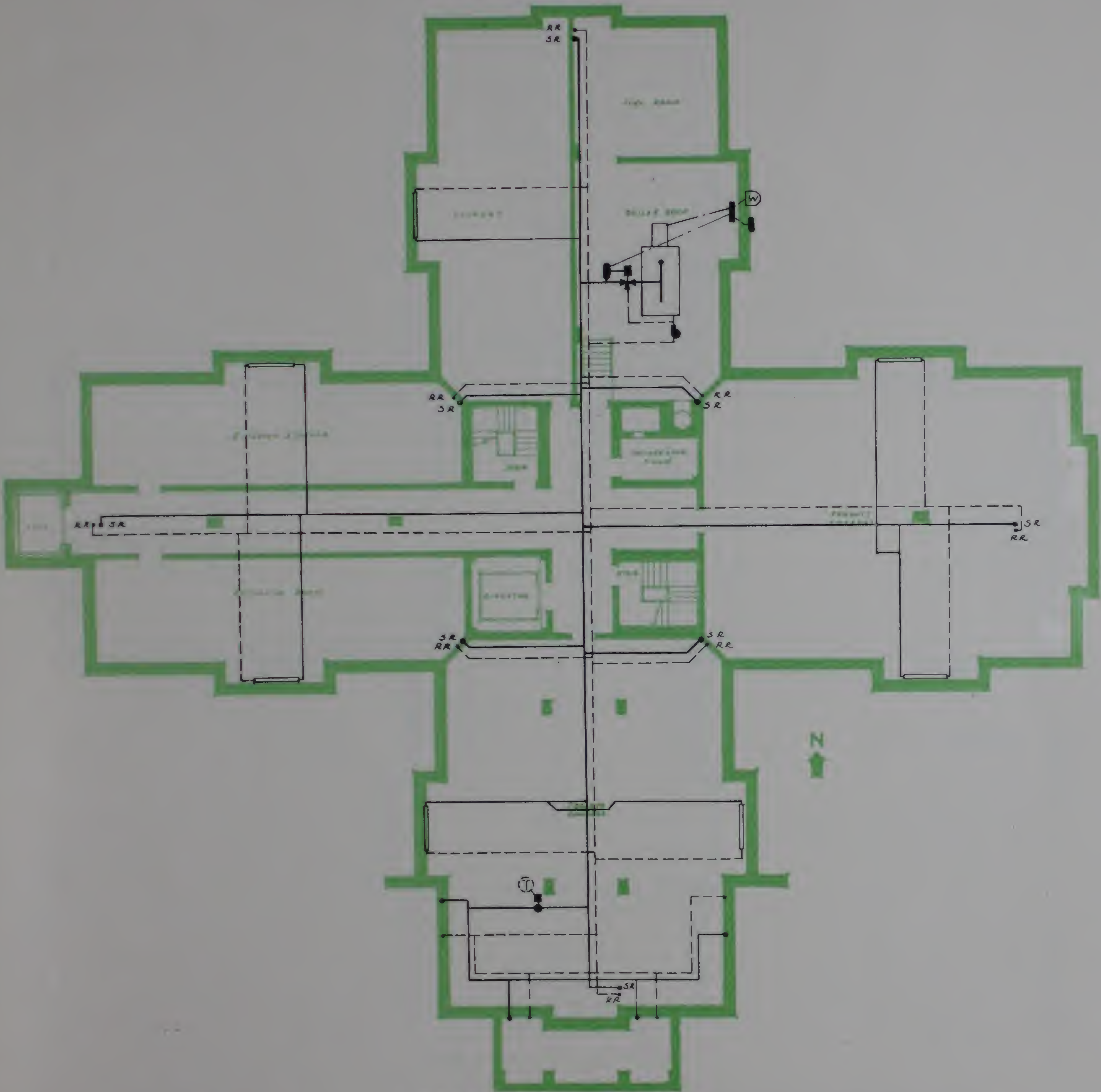


TYPICAL FLOOR PLAN

Type of Heating System—2 Pipe Hot Water
Piping Layout—8 Supply Risers, 8 Return Risers

Control—	*One Room Apartments* One thermostat located in the living room controls a valve supplying hot water to all radiators.
One and Two-Bedroom Apartments	One thermostat located in the living room controls a valve supplying hot water to the radiators in the living room, dining room and kitchen. One thermostat located in each bedroom controls a valve supplying hot water to the radiators in the bedroom and bathroom.
Three-Bedroom Apartments	Same control setup as in other bedroom apartments except that the thermostat in the center bedroom controls a valve supplying hot water to two bedrooms and the common bathroom.

LAYOUT NO. 5

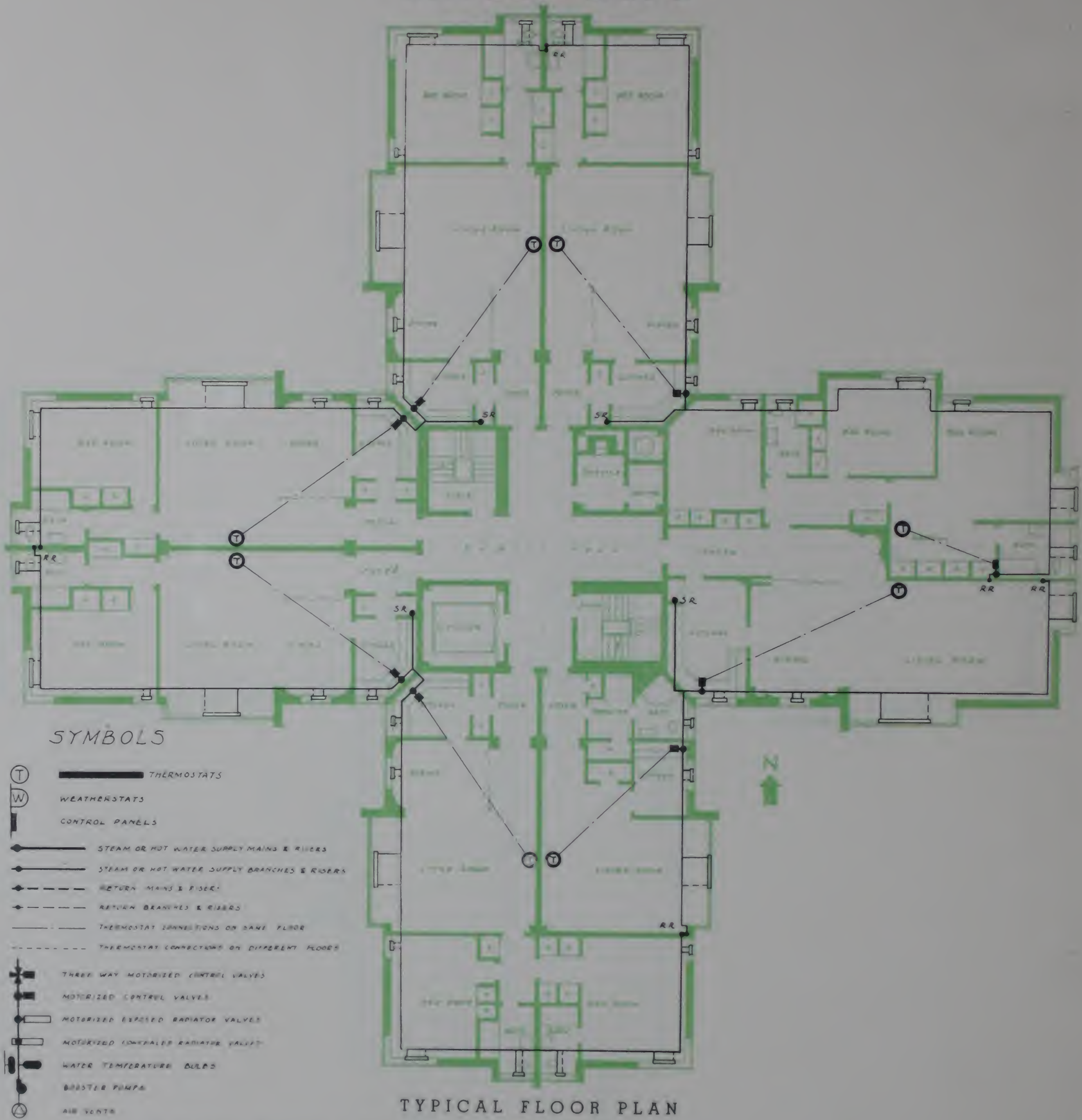


BASEMENT FLOOR PLAN

Outside Controller—A compensated control with one bulb located in the hot water supply line to the radiation provides for hot water to the radiation at predetermined temperatures based upon outdoor temperatures to provide for the greatest fuel economy.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 6

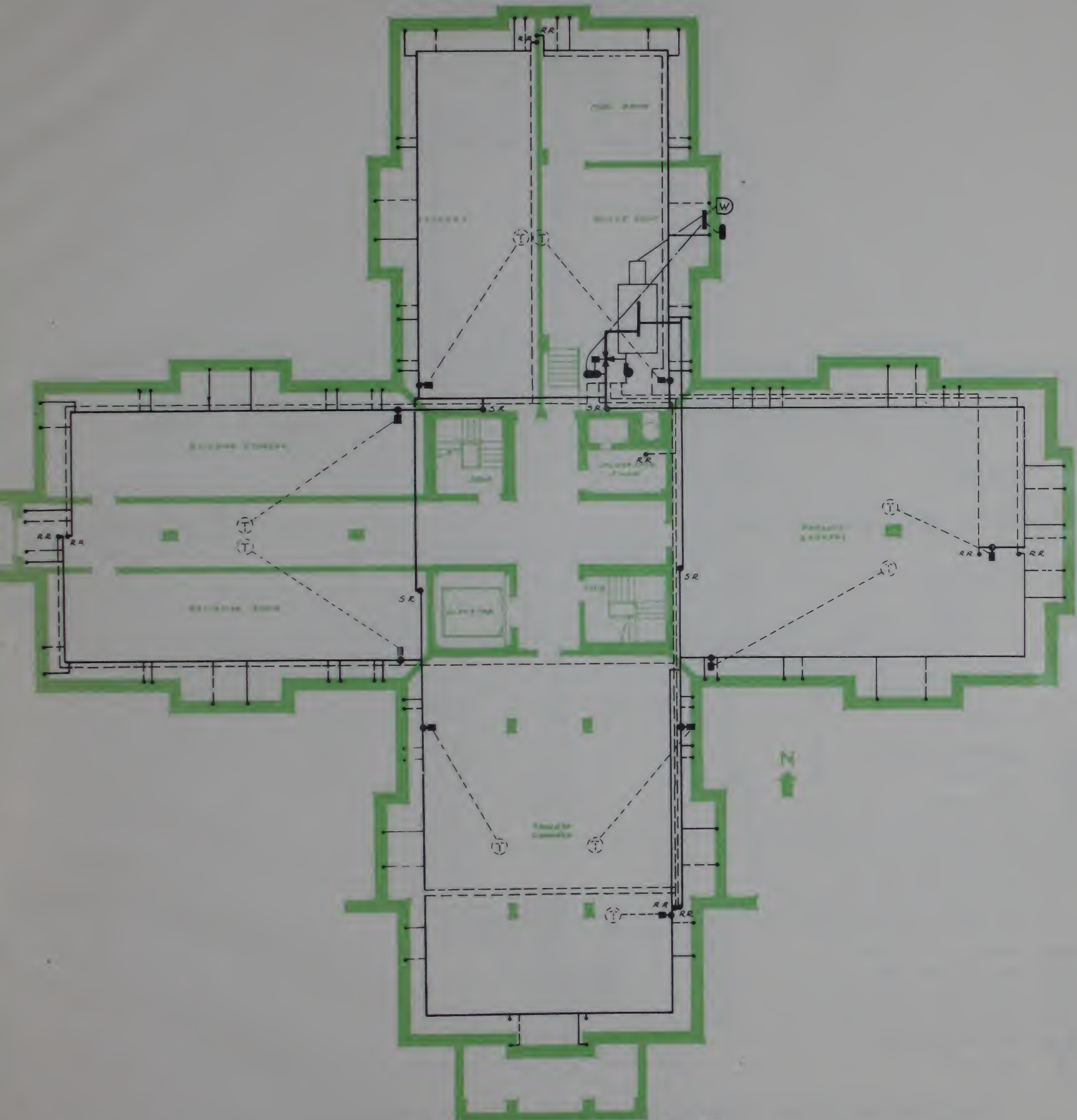


TYPICAL FLOOR PLAN

Type of Heating System—1 Pipe Hot Water
Piping Layout—4 Supply Risers, 8 Return Risers

Control—	*One Room Apartments*
	One thermostat located in the living room controls a valve supplying hot water to the radiators in the living room and kitchen.
	Bathroom radiators are not automatically controlled.
	One and Two-Bedroom Apartments
	One thermostat located in the living room controls a valve supplying hot water to all radiators.
Three-Bedroom Apartments	One thermostat located in the living room controls a valve supplying hot water to the radiators in the living room, dining room and kitchen.

LAYOUT NO. 6



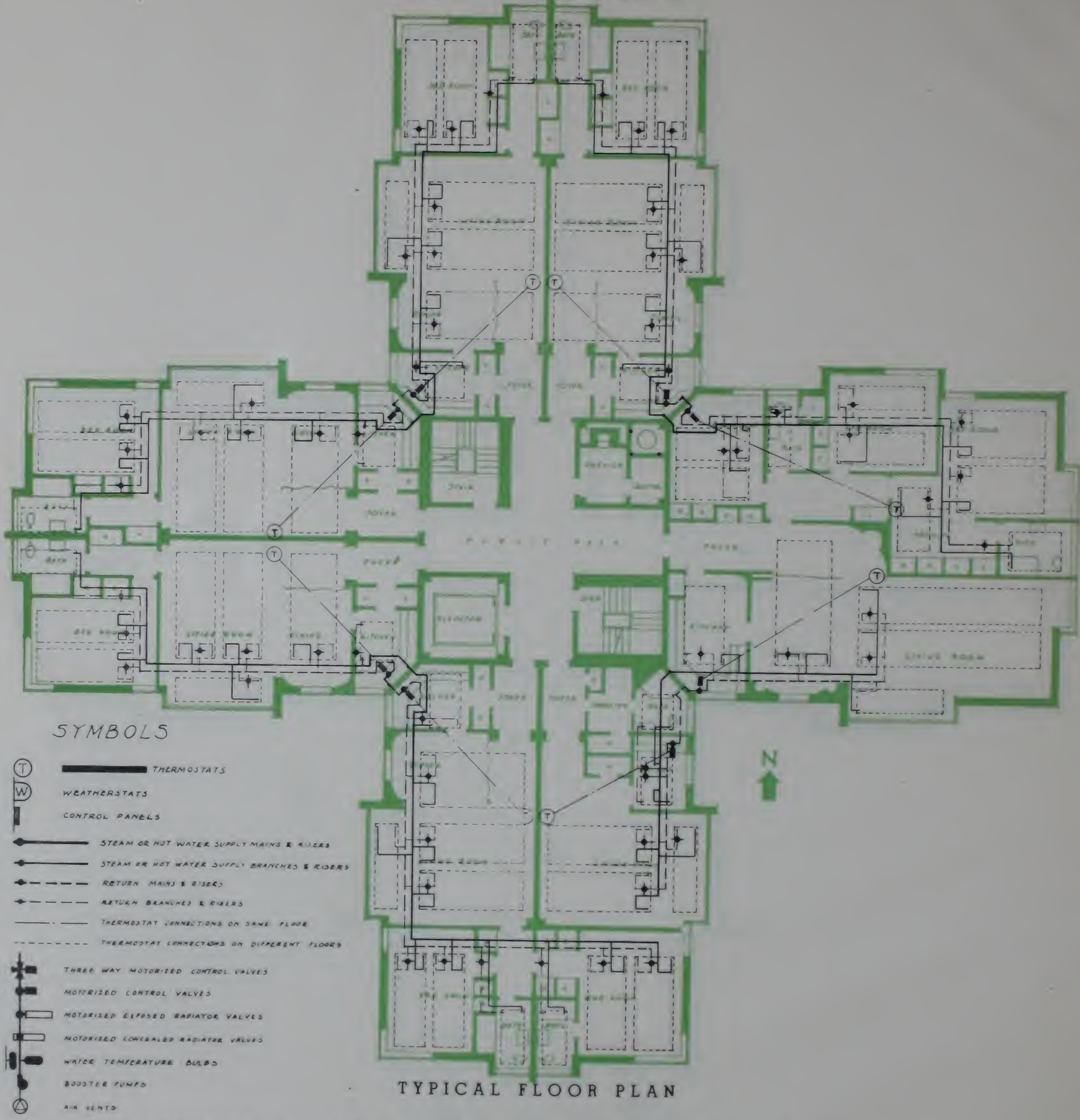
BASEMENT FLOOR PLAN

One thermostat located in the corner bedroom controls a valve supplying hot water to the radiators in all bedrooms and bathrooms.

Outside Controller—A compensated control with one bulb located in the hot water supply line to the radiation provides for hot water to the radiation at predetermined temperatures based upon outdoor temperatures to provide for the greatest fuel economy.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of a clock type electric thermostat or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 7



TYPICAL FLOOR PLAN

Type of Heating System—2 Pipe Hot Water Radiant (Heating Panels in Ceiling)

Piping Layout—4 Supply Risers, 8 Return Risers

Control—

One Room Apartments

One thermostat located in the living room controls a valve supplying hot water to the heating panels for the entire apartment.

One and Two-Bedroom Apartments

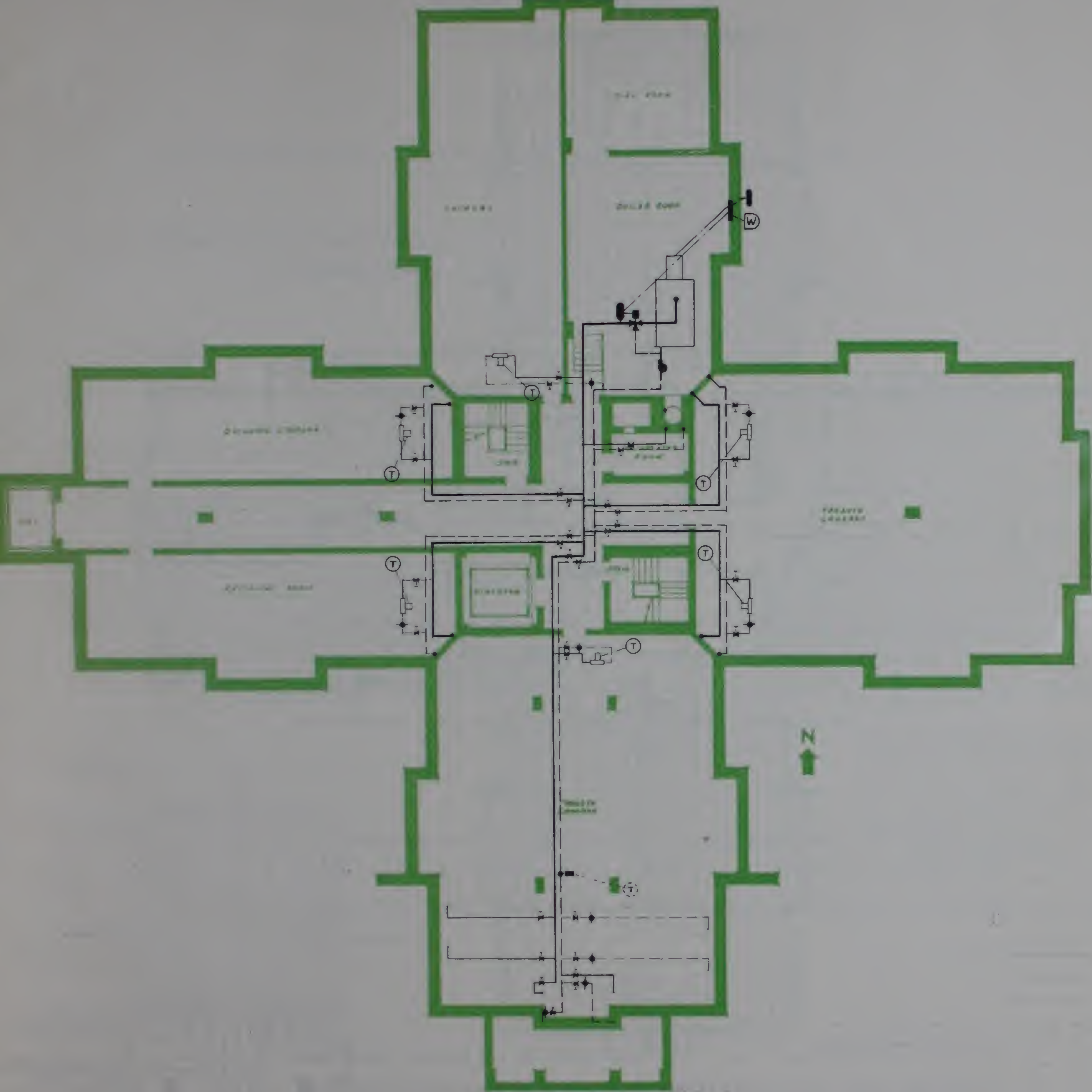
Same control setup as in the one room apartments.

Three-Bedroom Apartments

One thermostat located in the foyer controls a valve supplying hot water to the heating panels of the living room, dining room and kitchen.

One thermostat located in the corner bedroom controls a valve supplying hot water to the heating panels in all bedrooms and bathrooms.

LAYOUT NO. 7

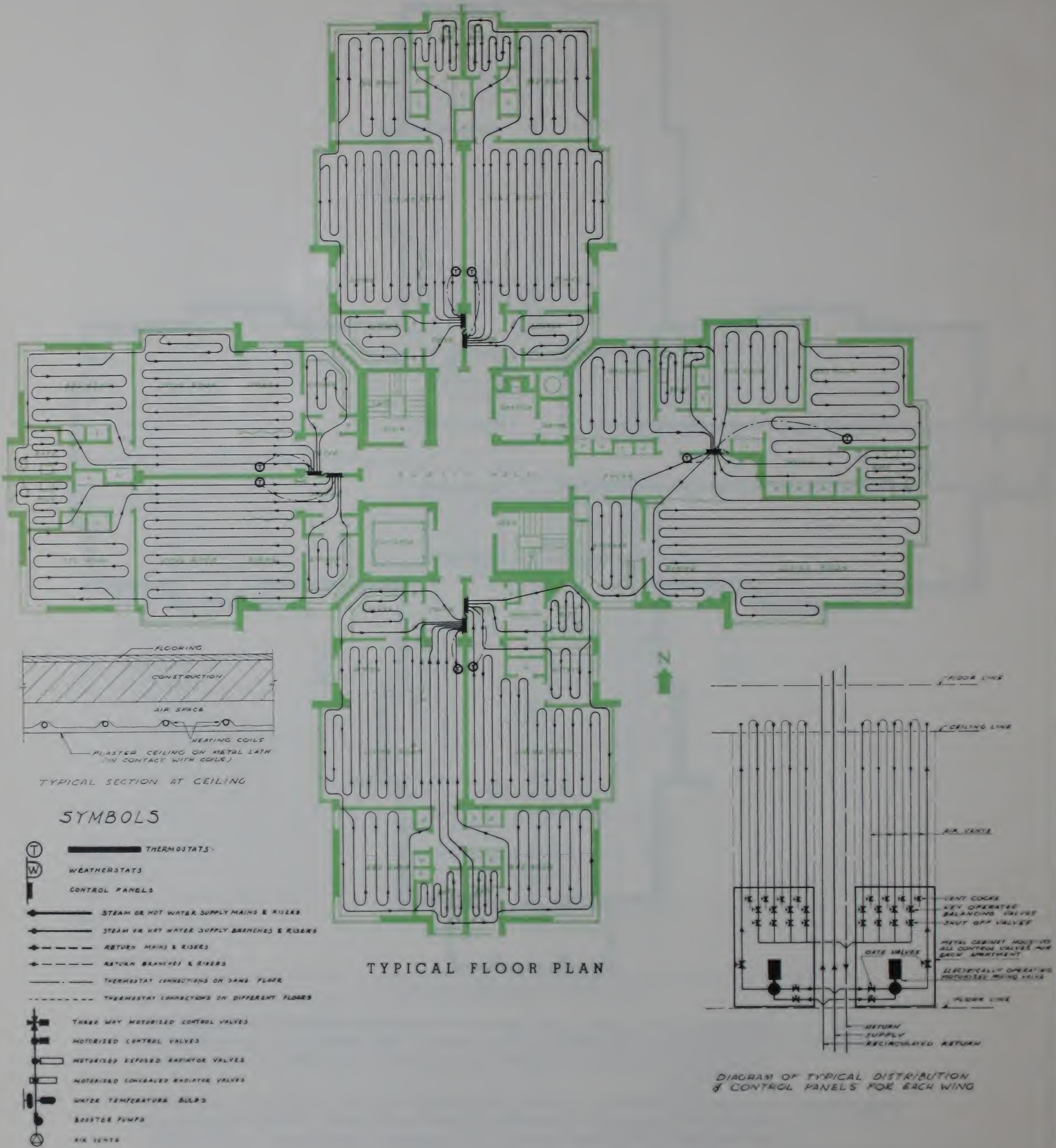


BASEMENT FLOOR PLAN

Outside Controller— A compensated control with one bulb located in the hot water supply line to the radiation provides for hot water to the radiation at predetermined temperatures based upon outdoor temperatures to provide for the greatest fuel economy.

Night Control—Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 8



TYPICAL SECTION AT CEILING

SYMBOLS

TYPICAL FLOOR PLAN

DIAGRAM OF TYPICAL DISTRIBUTION & CONTROL PANELS FOR EACH WING

LAYOUT NO. 8

Type of Heating System—2 Pipe Hot Water Radiant (Pipe Coils in Ceiling)

Piping Layout—4 Supply Risers
4 Return Risers

Control—

One Room Apartments

One thermostat located in the living room controls a valve supplying hot water to all the heating panels.

One and Two-Bedroom Apartments

Same control layout as in the one room apartments.

Three-Bedroom Apartments

One thermostat located in the living room controls a valve supplying hot water to the heating panels in the living room, dining room and kitchen. One thermostat located in the corner bedroom controls a valve supplying hot water to the heating coils in all bedrooms and bathrooms.

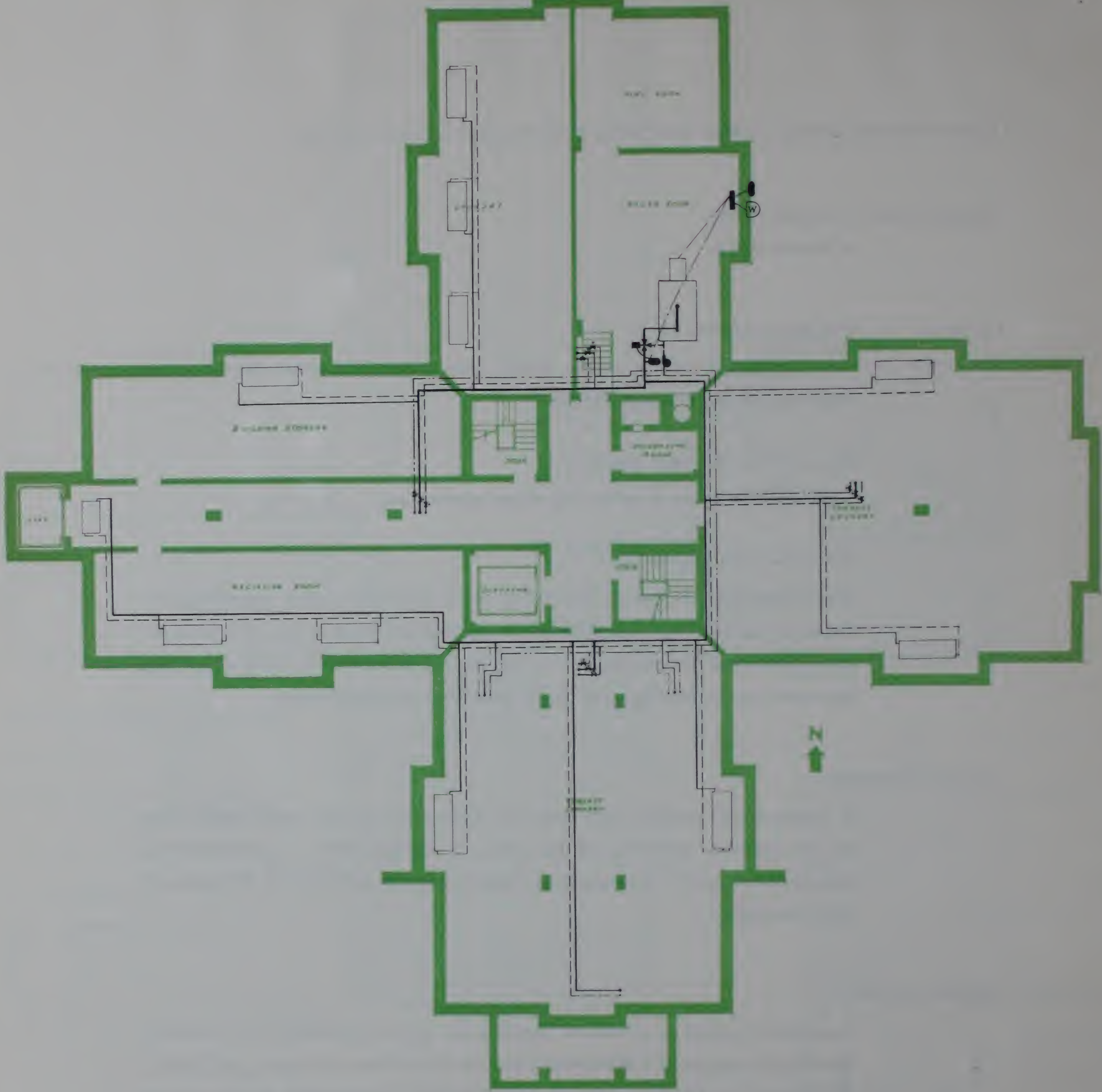
Outside Controller—

A compensated control with one bulb located in the hot water supply line to the radiation provides for hot water to the radiation at predetermined temperatures based upon outdoor temperatures to provide for the greatest fuel economy.

Night Control—

Automatic control at a reduced temperature may be provided for the entire building by means of a Weatherstat System or by means of clock type electric thermostats or Da-Nite (electric or pneumatic) thermostats in the various rooms of each apartment.

LAYOUT NO. 8



BASEMENT FLOOR PLAN

PERSONALIZED APARTMENT CONTROL

APPLICATION OF AUTOMATIC CONTROL VALVES

Steam Heating Systems

One Pipe—Modulating control valves should never be applied to a one pipe steam heating system because of the problem of returning condensate to the boiler in the same pipe flowing opposite to the direction of steam flow. With the valve only partially open condensate cannot flow against the steam under pressure.

Two position valves applied only at each individual radiator are recommended. The valves will be fully opened or fully closed and when in the wide open position condensate will leave the radiators readily.

Two position zone valves may be used, with caution, on one pipe wet return systems by applying drip traps on the upstream side of all valves and connecting the traps to the wet return.

Variable orifice vent valves are recommended on one pipe systems where zone valves are used to facilitate balancing of the radiation and adjustments for even steam distribution.

The following valves are recommended for control of one pipe steam heating systems:

V205A— ¾″ to 2″ Electric Radiator Valve

K200B— ½″ to 3″ Electric Motorized Valve for zone control

K201B— ½″ to 6″ Electric Motorized Valve for sizes larger than K200B

Pneumatic valves may be used but in all cases a positive relay must be used to assure two position operation.

V0500A—½″ to 2″ Pneumatic Radiator Valve

V052B— ½″ to 1″ Pneumatic Radiator Valve

K0900A—½″ to 3″ Pneumatic Gradutro Valve for zone control

K0901A—½″ to 3″ Pneumatic Gradutrol Valve for zone control

V053— ½″ to 6″ Pneumatic valve for zone control

Two Pipe—Either two position or modulating valves may be used with two pipe vapor or vacuum steam heating systems. Since condensate is returned to the boiler through a separate return line modulating valves are satisfactory.

If modulating zone valves are used each radiator should be equipped with a properly sized orifice to assure even steam distribution when the valves are only partially open. Radiator orifices are also desirable in connection with two position zone valves for the purpose of properly balancing the radiation.

On all two pipe systems modulating valves are more satisfactory because by throttling steam input more uniform radiator temperatures will be maintained and only enough steam will enter the radiation to offset heat loss from the space.

The following valves are recommended for control of two pipe steam heating systems:

V205A— ¾″ to 2″ Electric Radiator Valve

K200B— ½″ to 3″ Electric Two Position Motorized Valve for zone control

K900B— ½″ to 3″ Electric Modulating Motorized Valve for zone control

K201B— ½″ to 6″ Electric Modulating Motorized Valve for zone control

K901B— ½″ to 6″ Electric Modulating Motorized Valve for zone control

V0500A—½″ to 2″ Pneumatic Radiator Valve

V052B— ½″ to 1″ Pneumatic Radiator Valve

K0900A—½″ to 3″ Pneumatic Gradutrol Valve for zone control

K0901A—½″ to 3″ Pneumatic Gradutrol Valve for zone control

V053— ½″ to 6″ Pneumatic Valve for zone control

Hot Water Heating Systems

One or Two Pipe—Either two position or modulating valves may be used with either type of hot water heating system. However, if modulating valves are used on two pipe hot water heating systems, a reversed return piping arrangement to the radiation must be used to assure the same pressure drop through the piping to each radiator. If a reversed return piping system is not used the radiators nearest the valve will have a tendency to receive all the water when the valve is in the partially open position.

If certain radiators will be subjected to ambient temperatures below freezing a minimum flow should be provided when the valves are in the closed position by drilling a small hole through the valve disc.

The valves recommended for control of either one or two pipe hot water heating systems are the same as those recommended for control of two pipe steam heating systems.

THERMOSTATS

Two position electric valves may be controlled by any of the following thermostats:

T21A— Acratherm for manual adjustment only.

T209A— Da-Nite Acratherm for manual lowering of temperature but with automatic return to normal at a predetermined time.

T211A— Chronotherm for automatic lowering of temperature at a predetermined time with automatic return to normal at a predetermined time.

Modulating electric valves are controlled by the:

T92A— Modulating Thermostat for manual adjustment only.

All pneumatic valves may be controlled by any of the following thermostats:

T0900A—Gradustat for manual adjustment only

T0900B—Da-Nite Gradustat for manual adjustment and also for reducing the temperature setting from a remote point either manually or automatically.

LOWERED NIGHT TEMPERATURES

In most cases it will be desirable to provide for lowering the temperature of the entire building at night by cutting down the total amount of heat supplied, rather than leaving the lowering of temperatures to the individual apartment occupants. Each apartment may be equipped with an electric clock thermostat (Chronotherm) or a pneumatic Da-Nite Gradustat either of which will provide for automatically lowering and restoring the temperature at predetermined times each night and morning. With either of these thermostats the occupants may restore the temperature setting to normal after the night shutdown if desired.

The Weatherstat System of Control is recommended for the control of lowered night temperatures in combination with either plain type thermostats or the type that provides for lowering temperatures at predetermined times. With the latter type of thermostats the temperature might be lowered in each apartment at 10:30 and those tenants desiring normal temperatures for a longer period of time could restore the thermostats to normal setting. Then at 12:30, for instance, control could revert to the Weatherstat System and the total amount of heat delivered to the building reduced.

The Weatherstat System may be placed in control of the heating medium by means of a time switch. On those systems where the boiler is not used for heating the domestic hot water, the Weatherstat would control the burner direct for night operation and the time switch would revert the burner to the control of the boiler Aquastat or Pressuretrol for day operation. If the boiler is used for heating the domestic hot water the circulating pump on hot water heating systems would be operated intermittently by the Weatherstat at night and reverted to continuous operation during the day. On steam jobs, a motorized valve must be installed in the main supply header to be operated by the Weatherstat at night and placed in the wide open position for day operation.

COMPENSATED CONTROL FOR HOT WATER SYSTEMS

On hot water heating systems it is always desirable to supply water to the radiation only slightly above the temperature required to maintain desirable space temperatures. Such a system will reset delivered water temperatures in accordance with outdoor temperatures resulting in fuel economies.

An outdoor bulb is connected to reset the control point of a controller in the delivered water. As the outdoor temperature drops the delivered water temperature is increased and vice versa. If the boiler is not used for heating the domestic hot water, the system would control the burner and vary boiler water temperature. If the boiler is used to heat the domestic hot water the boiler water would be carried at a constant temperature and the system would control a motorized three way mixing valve, mixing boiler and return water to vary the supply water temperature.

PERSONALIZED APARTMENT CONTROL

BOILER CONTROL SYSTEMS

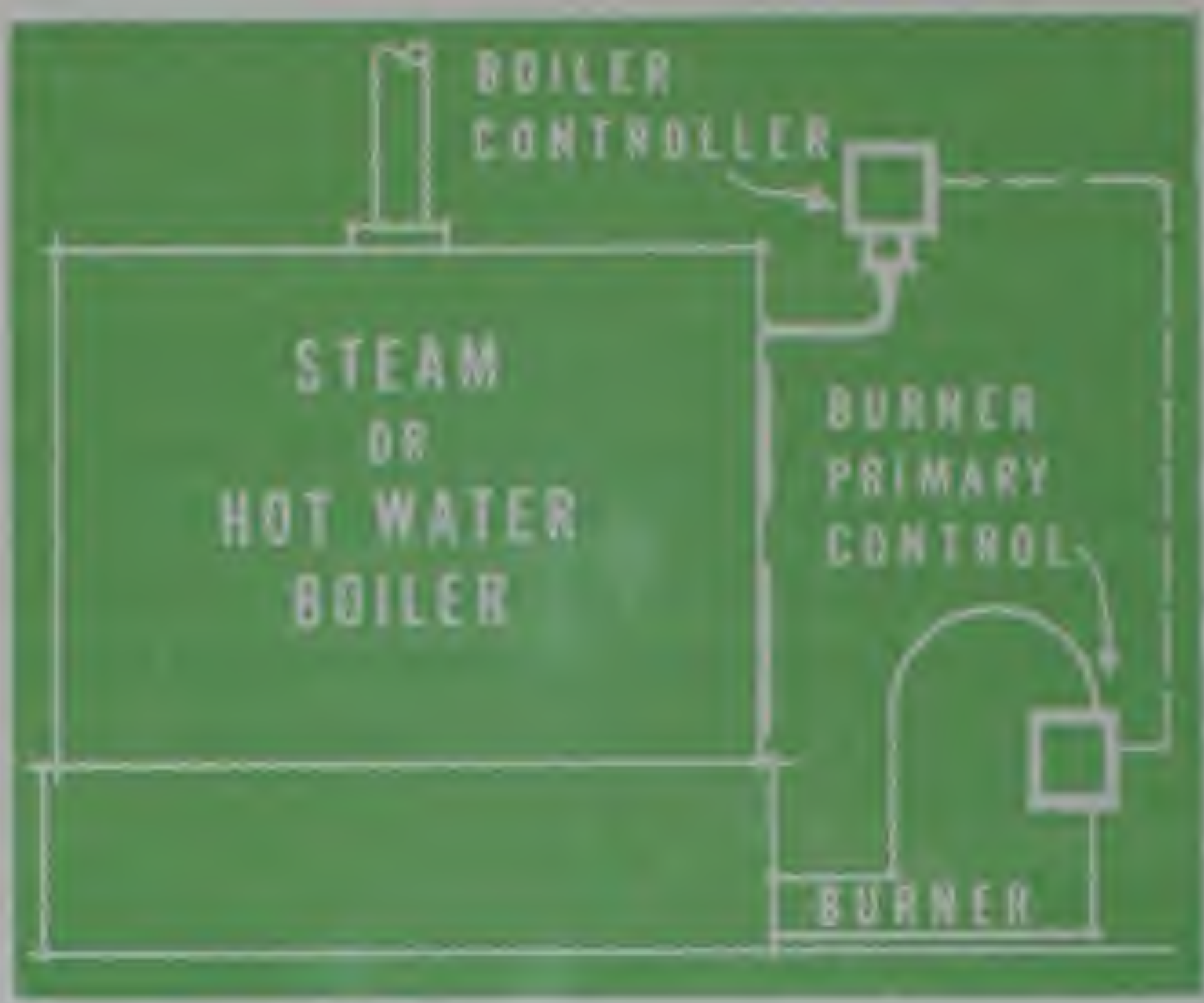


Fig. 1

The simplest method of boiler control is shown in Fig. 1. An Aquastat installed in a hot water boiler or a Pressuretrol installed on a steam boiler operates the burner or stoker to maintain the hot water at a constant temperature or the steam at a constant pressure. Thus hot water or steam is always available at the control valves when required by the individual apartment systems of automatic temperature control.

With this type of system the setting on the Aquastat or Pressuretrol must be high enough for the maximum heat requirements of the building.

Control valves of either the two position or modulating type usually produce a graduated or slowly varying load on the boiler and burner. The most desirable form of burner control system would be the type which modulates or proportions oil, gas or coal input in exact proportion to the load on the boiler so as to balance burner heat input with boiler output to maintain constant steam pressure or water temperature.

Two-position burner control is generally used and is perfectly satisfactory if the boiler has sufficient storage capacity to prevent too rapid cycling of the burner.

The Aquastat or Pressuretrol as shown in Fig. 1 therefore, may be either the modulating or two-position type with the proper burner primary control.

Primary burner controls would be selected for the type of burner used such as a gas valve for gas, a Protectorelay for oil or a Timerelay for a stoker. In addition to the controls shown such safety devices as a Lo-Water Cutoff for steam boilers and a pilot safety device for gas are always required; on very large gas fired boilers the Protectoglo Flame Safeguard System and on large oil fired boilers the Photoglo Combustion Safety System are recommended.

HOT WATER SYSTEMS—VARIABLE HOT WATER TEMPERATURES

Fig. 2 illustrates schematically an arrangement for regulating the heat output of a hot water boiler. The system provides for varying the temperature of the water delivered to the radiators in accordance with outdoor temperature. As the outdoor temperature drops the delivered water temperature is increased and vice versa with provision for varying the relationship between delivered water temperature and outdoor temperature for individual jobs.

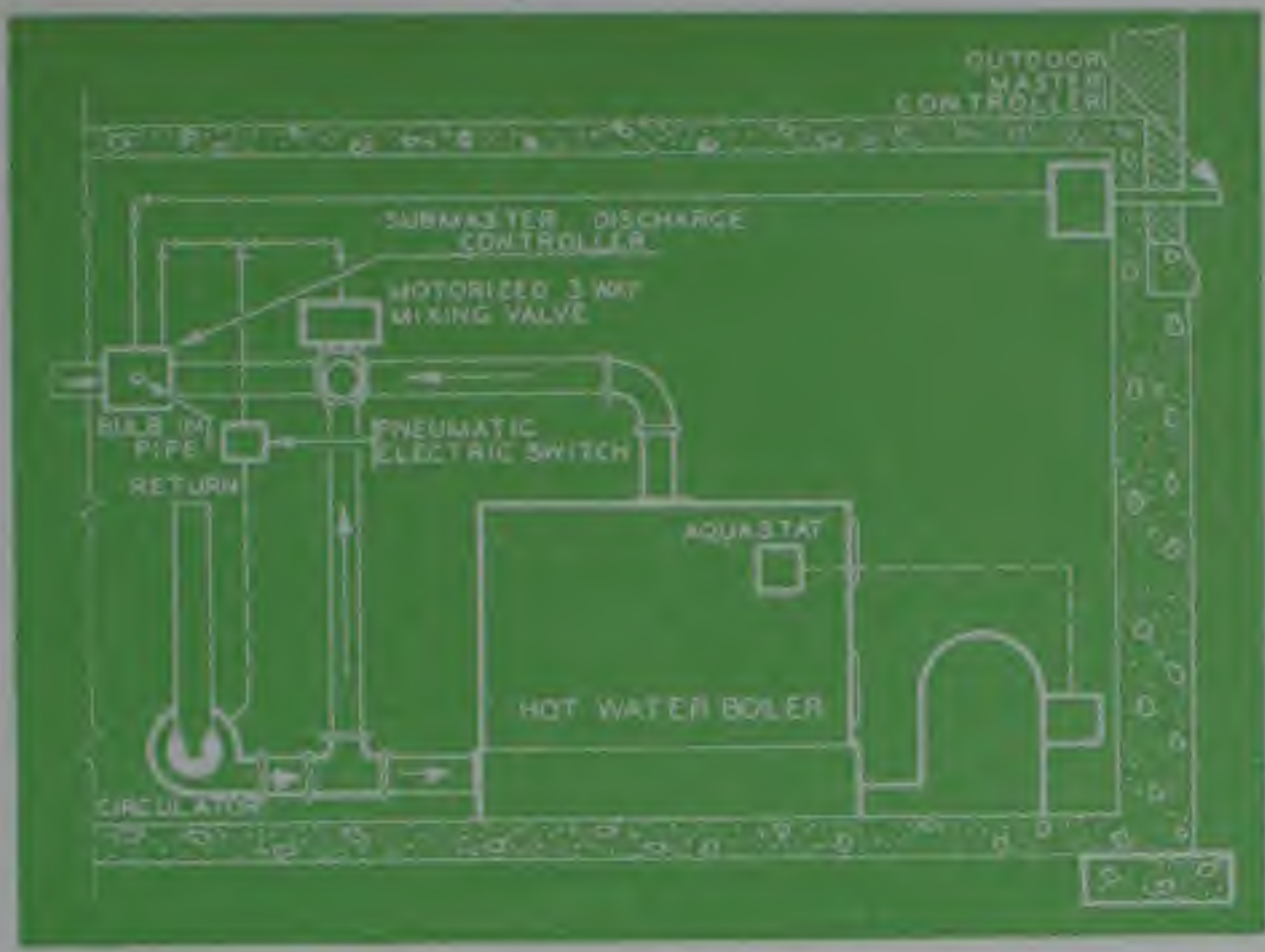


Fig. 2

It is always desirable to deliver water to the radiation at a temperature only slightly above that required to offset heat loss from the space. Such an arrangement will cause the control valves to remain open a larger percentage of the time resulting in more uniform radiator temperatures and less variation in space temperatures. This system is especially desirable for apartments since it can be used to limit the temperature of the delivered water for any given outdoor temperature which means that tenants cannot open windows excessively or carry individual apartment temperatures extremely high.

In the system illustrated the Aquastat operates the burner through the burner primary controls to maintain the boiler water at its setting. The setting on the Aquastat should be at the maximum water temperature required for the lowest outdoor weather conditions or if the boiler is used for heating domestic hot water it must be set at the point required to provide sufficient domestic hot water.

The Submaster Controller is mounted with its temperature sensitive element in the supply main to the radiation on the discharge side of the three way valve. The outdoor master controller measures outdoor temperature and resets the control point of the bulb in the supply water. The Submaster Controller controls the modulating motorized three-way valve which mixes return water and boiler water to deliver water to the radiation at the temperature called for by the Submaster in the supply water. A pneumatic-electric switch is connected to the circulator to stop the circulator when the three-way valve reaches the position that no hot water is delivered to the radiation from the boiler.

Fig. 3 illustrates schematically another arrangement of controls for regulating the heat output of the hot water boiler. This system provides for varying the temperature of the water delivered to the radiators in accordance with outdoor temperature similar to that as described for Fig. 2. The compensator is mounted with the bulb in the outdoor air and functions to reset the control point of the temperature controller which has its bulb immersed in the hot water boiler. The temperature controller controls the Series 90 relay which in turn, operates the primary burner control to maintain the desired boiler water temperature. As the out-

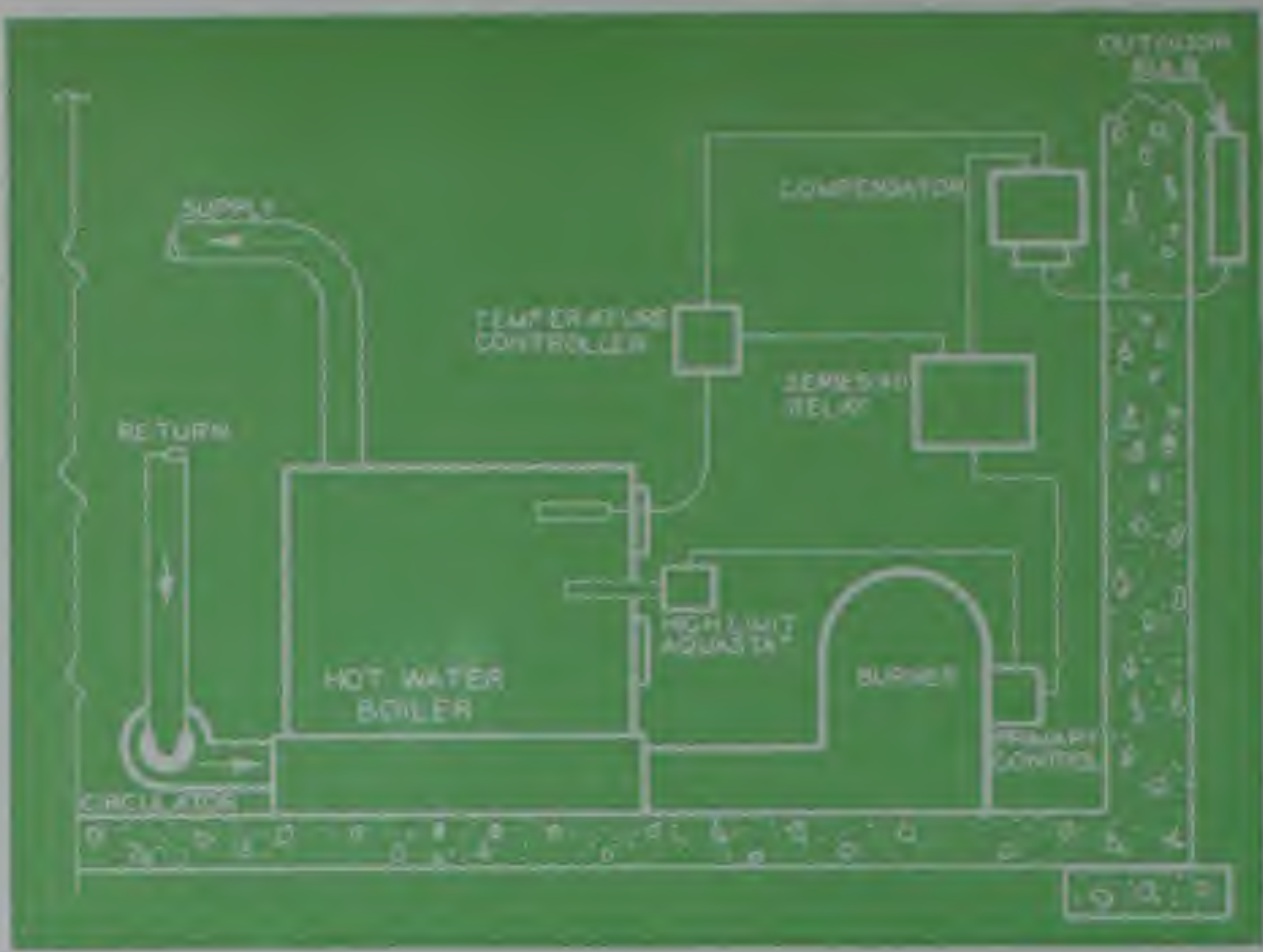


Fig. 3

door temperature drops it raises the control point of the temperature controller in the boiler and as the outdoor temperature rises, it lowers the control point of the temperature controller in the boiler to enable delivery of water to the radiation at a temperature only slightly above that required to offset heat loss from the space. The high limit control setting should be at the maximum water temperature required for the lowest outdoor weather conditions.

Fig. 4 illustrates a Weatherstat System of control applied to a steam or hot water boiler for the purpose of providing lowered night temperatures for the entire building.

At a predetermined time each night a time switch in the panel places the Weatherstat System in control of the heat delivered to the building and reverts control to the regular system at a predetermined time each morning. The Weatherstat is mounted outdoors and controls building temperatures in accordance with all weather factors which affect building heat loss.

The Weatherstat is, in effect, a small room placed out of doors which contains its own thermostat and heating plant in the form of an electric heating element. The thermostat in the Weatherstat controls the temperature within the Weatherstat and also controls the operation of the apartment heating system. As the temperature within the Weatherstat rises and falls, the heating element is turned on and off to maintain a constant temperature inside the Weatherstat. At

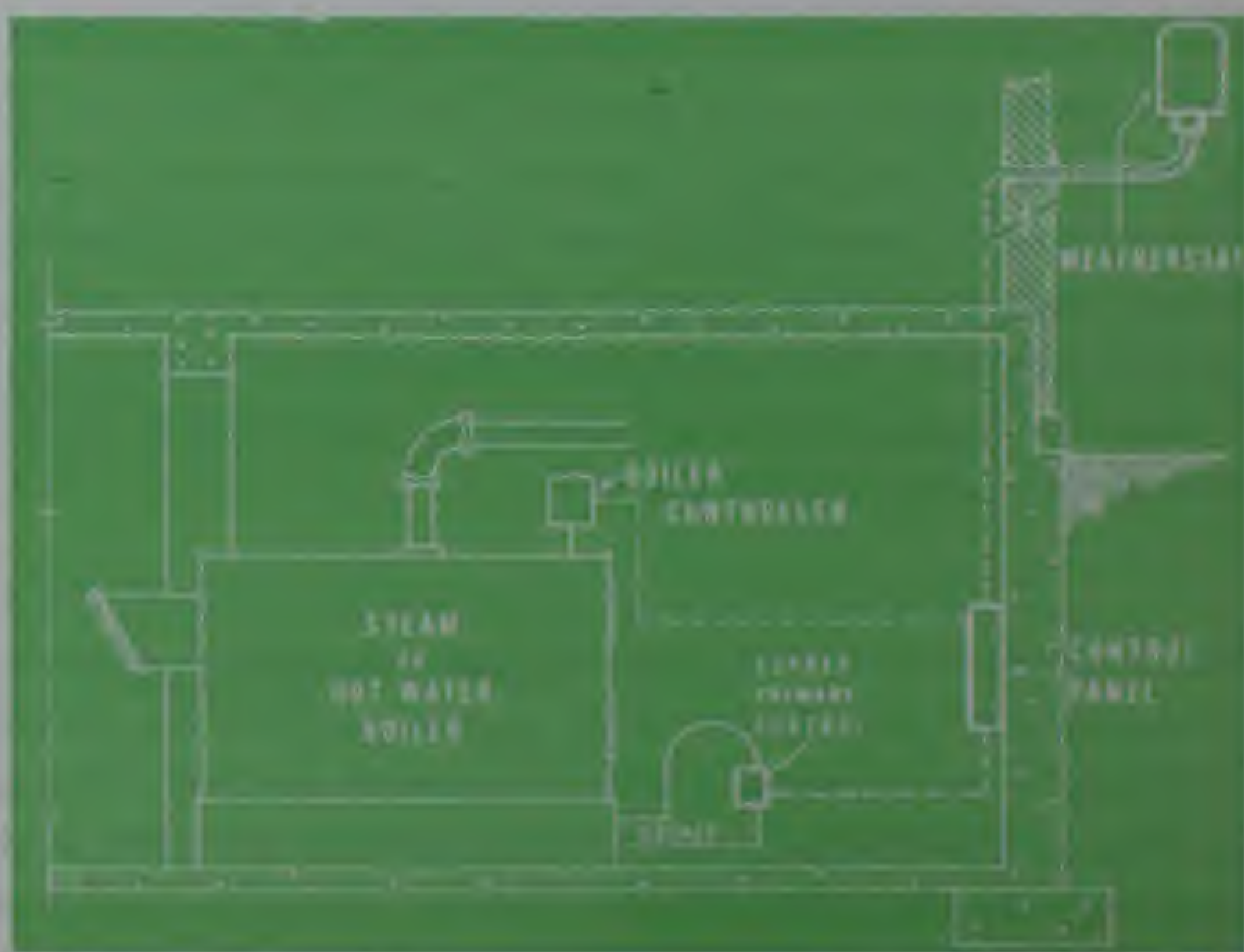


Fig. 4

the same time heat supplied to the apartment is turned on and off to maintain a constant building temperature. The Weatherstat System is adjusted so that its heating and cooling rate corresponds to that of the apartment building. Thus the Weatherstat becomes a miniature building which is used as a guide to determine the heat requirements of the apartment building.

The boiler control systems illustrated schematically in Figures 1, 2, and 3 and described above, are by no means the only systems available. Minneapolis-Honeywell does not attempt to adapt one or even several standard boiler control systems to all heating systems regardless of type, size or fuel used. Many types of boiler control systems are available to fulfill specific requirements and provide any control sequence desired.

It is recommended that careful consideration be given to the boiler control system selected to be sure that the system will provide maximum economy, flexibility and safety. Minneapolis-Honeywell is in the position of being able to recommend and supply the proper boiler control system for any particular job to provide all desirable features.

The time to give full consideration to Personalized Apartment Heating is when new apartment buildings are in the plan stage.

To design the heating system of an apartment building for adequate heating is not enough by present day standards. The heating system must provide controlled heating.

Sectional Heating is not possible unless the flow of heat to the individual apartments or apartment sections can be regulated independent of the heat flow to other apartments. *Only careful planning of the heat distribution piping can furnish the basis of a good Personalized Heating Control.*

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